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CDC 30353

AUTOMATIC TRACKING RADAR SPECIALIST

(AFSC 30353)

Volume 1

Maintenance Principles and Test Equipment



Extension Course Institute
Air University

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Preface

THE FIRST VOLUME of CDC 30353 is composed of six chapters that will acquaint you with subjects you need to become very familiar with in order to be an effective maintenance specialist. Chapter 1 starts off with an introduction to the career field and a small review of its past. This introduction gives you some background information that'll lead you into the rest of Chapter 1; career field related safety. Air Force publications are covered in Chapter 2. The CEM maintenance management covered in Chapter 3 will contain quite a bit of information you'll need early in your training and work. Chapter 4 introduces maintenance principles designed to enhance your abilities to maintain and care for your assigned equipment. Since you are being trained to become a repairperson, Chapter 5 will introduce you to the world of soldering. It will cover ideas and techniques you'll need to repair your equipment. Along the same line of thought, Chapter 6 will cover test equipment. Because of the vast numbers of test equipment being used in our career field, Chapter 6 is only a sampling of some of the more commonly used items.

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Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes, the examinee should check the Index of ECI Study Reference Material to determine the correct references to study.

Acknowledgement

ACKNOWLEDGEMENT is gratefully given to PACE, Incorporated, Tektronix, Incorporated, and Hewlett-Packard Company for permitting text and illustrations from their Instruction Manuals to be used in this CDC. Our discussion of the PACE Electronic Maintenance in Chapter 5, Section 5-8, is based on the PACE Instruction Manual.* The text relative to the Tektronix-Type 453 Oscilloscope in Chapter 6, Section 6-2, is based on the Manufacturer's Instruction Manual provided by Tektronix, Incorporated.** The information covering the HP 432A Power Meter in Chapter 6, Section 6-2 is based on the Operating and Service Manual, Power Meter 432A, provided by Hewlett-Packard Company.*** Each of these identified areas is used with the permission of PACE International, Tektronix, Incorporated, and Hewlett-Packard Company respectively.

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**Manual for Electronic Maintenance System, Model PRC-350C.* PACE, Inc., 9893 Brewers Court, Laurel, Maryland.

***Instructional Manual, Type 453/R453 Oscilloscope (above SN 20,000).* Tektronix, Inc., S. W. Millikan Way, P. O. Box 500, Beaverton, Oregon.

****Operating and Service Manual, Power Meter 432A.* Hewlett-Packard Company, 120 Century Blvd., New Jersey 07652.

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NOTE: This course teaches through numbered lesson segments, each containing a behavioral objective, text, and exercises. The objective sets your learning goal. The text gives you the information you need to reach that goal, and the exercises let you check your achievement. When you complete each segment, see whether your answers match those in the back of the volume. If your response to an exercise is incorrect, review the objective and its text.

Career Field Introduction and Safety

CONGRATULATIONS! You have successfully completed the basic technical school course and have been awarded the Air Force Speciality Code (AFSC) 30333, Automatic Tracking Radar Specialist, semiskilled level.

Welcome to "the field." By the time you receive this first volume of your Career Development Course (CDC), you'll probably no longer be "the rookie" on site. Usually it takes 6 to 8 weeks from the time you sign into your new unit until you receive your CDC package. Hopefully you received a good welcome and orientation to your new job and unit. In support of that orientation briefing, and to introduce these CDCs, we're going to cover a few things before we get into the real work of completing this CDC.

First, let's review a little of this career field's history and by doing so, maybe allow you to see why and how we've arrived at our present status. As you've probably already been told by some "Autotracker", this career field is a little different from most other career fields in the Air Force. The 303X3 career field is one of three related ground radar career fields. The other two are the 303X1 (Air Traffic Control Radar) and the 303X2 (Aircraft Control and Warning Radar) career fields. Those two career fields have radars similar to ours but their personnel do only maintenance work. As you've already been told, we 303X3 personnel maintain and operate our own radars. That's what makes us different. Many of the "older" people who've been around this career field for most of their careers prefer to think of 303X3 personnel as "special." This career field has always been the odd or different one of the three radar career fields. Our locations and duties also add to that "different" tag. The 303X3 career field has been around for more than 30 years. We started out as an evaluation tool to train and evaluate bomber crews. The Air Force, and the Strategic Air Command (SAC) in particular, wanted a way to practice bombing without dropping real bombs. The result became what we know today as radar bomb scoring (RBS). Also, even back in the 1950s and 1960s, we were providing electronic warfare (EW) and electronic countermeasures (ECM) threat simulation.

Once the Air Force saw that our radars could acquire an aircraft and then track it to its bomb release point above a target, it was reasoned that we could also guide an aircraft to a point in the sky where, if performed properly, a bomb load could be dropped to hit enemy targets on the ground. This was how we got started in the bomb directing business, later called ground directed bombing (GDB). Our radars were used for some GDB in the Korean Conflict/War.

Later, during the situation in Southeast Asia (VietNam, etc.), our radars were again used for GDB.

In the early 1970s, a strong push was placed on the EW/ECM training provided to aircrews. Again, the 303X3 career field was expanded to include newer radars to provide this EW/ECM threat simulation. The RBS work continued and the GDB work slackened.

Today, we're still doing the RBS and the EW/ECM threat training on a regular basis. The GDB work isn't done that much anymore. The radars we work with today cover over 40 years of technology, exist in more than 30 different systems, and the operator positions total an unknown amount. The major users of the career field are SAC and the Tactical Air Command (TAC). SAC uses us for RBS and EW/ECM while TAC, and its associated commands, use us primarily for EW/ECM threat simulations. Because we work with flying aircraft, we often find ourselves working on radar sites located away from bases, large cities, or any congested airspace. Because these radar sites are semiremote from support facilities, we 303X3 personnel often find ourselves having to work on equipment other than our own radars. We frequently have to work on air conditioners, air compressors, heaters, frequency converters, and just about anything else on a site, including plumbing and carpentry. We set up, tear down, move, or even build our own sites. As you can see, we're different. That's also the reason the "old timers" think 303X3 people are special.

When you completed technical school and obtained your 3 level, you had reached the first step on the career ladder. The upgrade work (CDCs and operations/maintenance training) you're just starting is the second step to be taken. Most units require both operations and maintenance tasks to be done prior to being upgraded to the 5 level. These CDCs are of course mandatory. Once you complete your 5-level upgrade training, the training won't end. You'll continue on to become 100% qualified on your assigned radar and, if necessary, operator qualified on other positions. Sooner or later you'll become a trainer to a new "rookie" and possibly even become an equipment supervisor, even as a first term. As you progress through the upgrade training keep these things in mind and do your best.

As you can see, the 303X3 career field could well be described as a jack-of-all-trades career field. Generally speaking, we're specialists who can do a little of everything. The following pages, chapters, and volumes of this CDC are designed to help you understand and progress in this career field.

As often is the case, safety will be our first area covered. You've already seen that we do a large number of our jobs in some semiremote areas. The way we work, day in and day out, may sometime present real life or death situations. Emergency care is not always immediately available to us. Because of this lack of immediate care, accident prevention is extremely important. In the case of an accident, your knowledge and ability to assist the victim then becomes even more critical.

In this chapter we're going to discuss some career field related safety hazards, safety precautions, and your actions in response to accidents. Some areas may seem like we're trying to scare you away from the career field but those areas are just trying to describe the "real world" in which we work. The items covered are career field related and are rarely, if ever, covered in any other publication. If you read this information and find you still have questions concerning an area, one of the senior supervisors on site should be able to help clarify your questions.

1-1. Safety Hazards

One of the problems everyone faces when placed into a new environment is that of identifying the boundaries. In the case of safety, we identify these boundaries as hazards. In our business, hazards can be both visible and invisible. You must be trained to identify both.

001. Identify possible job hazards related to the 303X3 career field.

Radiation. During the orientation to your new unit, you should have been briefed on the possible radiation hazards that exist around the radar site. Although some of our radars pose no hazards, others can do serious damage to living beings. There's probably a radiation chart somewhere on your site or in your workcenter, that shows the radiation pattern of each radar. Most charts are color-coded to indicate the amount of radiation hazard around each radar. If no charts exist, look for the red and black, diamond-shaped signs like the one shown in figure 1-1. These signs are posted in areas where radiation hazards exist. They should be found at roof edges when you're climbing up to a rooftop area. They'll also be mounted on posts around the site or workcenter area. The only time it's safe to go into these hazardous areas is when the transmitter in that area is turned off. Be aware that radars from another side of the site may also pose a hazard. Know the radars on your location, if they're dangerous, and when they're radiating.

Another radiation hazard exists in some of the tubes used by some of our radars. Certain tubes contain radioactive material and as long as the tube is intact, no danger exists. A small collection of such tubes presents little or no hazard but when a large quantity exists in the same small or close area, the radiation hazard becomes real. The danger comes when a radioactive tube is accidentally broken. A potential hazard exists by inhaling or ingesting the radioactive material. Certain tubes used such as klystrons, thyratrons, magnetrons, or other such transmitting tubes can have radioactive material in them.

It's your responsibility to know about radiating radars and radioactive tubes and to protect yourself. Female personnel (and dependent females) should especially be aware of radiating radars and their possible hazards while the female is pregnant. They should consult their doctor for advice and guidance. Radiation is an invisible hazard and can damage a human body. Since it is invisible, you must know how to identify its hazards. If in doubt, ask your supervisor.

Electrical Shock. Because of the nature of our business, electrical shock is a continuous hazard that we have to live with. We're taught from day one in this career field to respect the electrical equipment that we work on and to always be on guard against becoming an electrical shock victim. The fact is, sooner or later, you're going to be a victim of electrical shock in one form or another and at different degrees of severity. Anyone who stays in this career field for any length of time is going to get shocked by electricity. Most often the shock is only a small amount, causing a minor jolt to the receiver (you). Due to the ever present safety precautions used, this is normally the maximum you'll encounter. Whether minor or major, electrical shock hazards exist in any piece of equipment that we work on or around. Your job is to follow the safety precautions and always know, and be aware of, potential electrical shock hazards. Shock hazards can exist for both an operator and a maintenance person. Operators have to open cabinets or drawers to make minor adjustments to the equipment. Every time a radar's door or drawer is opened, an electrical shock hazard exists. Personnel performing maintenance have to do more than just make minor adjustments to the equipment. They often have to do alignments to the equipment, inside very restricted areas, with power applied. The electrical shock hazard here is twofold. First, there's the danger of getting shocked. Secondly, there's the danger from the victim's reaction to being shocked. Frequently, the shock is very minor but the victim has a tendency to quickly back away from the danger. This quick, often times uncontrolled, movement can result in more damage to the victim. A hand or arm jerked away from the shock source is often gouged, punctured, or even thrown into another nearby electrical hazard. The point is, try to prevent the initial shock to start with. If that isn't possible, try to control the reaction. And remember, never work on electrical equipment alone. We use the "buddy system" where either you or your "buddy" will be the safety observer. As stated earlier, most electrical shocks are minor and result in minor damage. There is also the potential major electrical shock where the victim gets shocked and "hung up" or attached to the shock source. Someone has to be present to kill the power, attempt removal of the victim from the shock source, and to start first aid. That someone will be the buddy or safety observer.

Another electrical shock hazard exists with equipment units that have been disconnected and removed from the main equipment for bench checks or repairs. Just because a unit is disconnected and removed does not make it safe to touch. Certain electrical circuits have enough residual charge left in them to kill you. Always be conscious of this



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Figure 1-1. RF Radiation Hazard Sign.

fact and always use a grounding stick or rod to eliminate any possible residual voltage prior to working on or around the unit. Along this same line of thought you must also be aware of individual components that can also store a charge. Just because a component is removed from a unit and is lying on a workbench, it isn't necessarily safe. Large capacitors, for example, have specific handling directions because they can acquire large quantities of static charge if not properly grounded and shorted.

Equipment grounding is another problem on any radar site. Although the lack of proper grounding rarely exists, there are occasions where an electrical shock will be caused by poor equipment grounding. If you ever receive a shock when you touch a trailer or shelter housing electrical

equipment, immediately report it to a supervisor. Most of our radars are housed in metallic trailers or buildings and if everything isn't properly grounded, electrical shock is possible. Equipment grounding straps occasionally become loosened or get broken accidentally and can go unnoticed. These loose grounding straps can do damage to you and can cause damage to the operating equipment. Grounding straps are periodically checked and evaluated but situations do occur where the ground becomes unattached and becomes a hazard.

Remember, electrical shock hazards exist everywhere. Your job is to identify the hazard, try to prevent becoming a victim, and if the situation ever happens where an electrical shock occurs, know how to react to it.

Heights. Anytime a person is placed into a situation of being raised above the normal walking surface, the potential for a fall exists. Personnel in this career field work on radars that are always above the normal walking surfaces. We work inside the radar vans and, in most cases, this poses no hazard. The height hazard comes into play when we have to go outside the radar shelter. Almost every radar we have requires us to go outside and to climb up onto the top of a van, or at least up to a raised work platform. Any time we have to climb, we are placed into a hazardous situation and extra care must be taken. On almost every radar, we are required to be at least 6 feet or more above the ground. While most of our radars average 15 to 25 feet in height above the ground, there are some special situations where we may have to climb to heights up to 50 feet. As you can see, there's always the hazard or potential of falls. A fall from a work platform only 6 feet above the ground can result in serious damage to the victim.

Another problem with working atop radars is the weather elements. Moisture, wind, and cold adds to the work problems while up on a radar. Safety rails or ropes are available on many systems to keep you from slipping or being blown off. Some of our radars, because of their design, can not use the safety rails or ropes. In these situations, most safety directions require safety belts or harnesses. Cold weather also slows your physical and mental reactions. Added to the slower reactions is the restrictiveness of the winter clothing. All these elements make working at heights a definite hazard.

Personnel working on raised work areas should also be aware of the hazard caused by dropped or falling objects. If you're the person up on the raised area, you must take precautions to ensure that objects are secured and not allowed to drop. If you're the person on the ground or on a lower level under the raised work area, you must be aware of possible falling objects. Most units require hard hats for safety, but hard hats don't always prevent injury from falling objects.

Remember, if you're required to climb, take all of the aforementioned situations into consideration. The job up on the radar has to be done by someone and that someone has to face the hazard. As with all the other hazards we're discussing, identification of the hazard is the first step. Be aware of height hazards and then handle each situation as it happens.

Noise. The noise hazard in this career field can come in several different ways. These hazards are often overlooked or taken for granted as being just part of the job. Most of our radars must have air blown through them to keep them cool. These blowers cause high frequency noise hazards. The actual noise isn't all that loud but the constant, high-pitched whine can cause hearing damage to personnel working in those areas. Our radars also have some motors that give off similar high-pitched whines. Almost every radar site has converter units that change 60 Hz into 400 Hz and these converters, when fully run up, will cause high frequency noise hazards. Any noise area is supposed to be well identified or marked, and it is your responsibility to know these areas and to take the appropriate precautions.

Another noise hazard area that relates mostly to the Tactical Air Command (TAC) 303X3 personnel, but can

apply to us all, is the noise produced by the large M-series vehicles used in this career field. Check local directives concerning the noise hazards of any particular vehicle. If in doubt, use your ear protectors.

Lifting. Lifting hazards depend upon the object's weight, bulk, and the individual doing the lifting. In this career field, we repair, tear down, and install radars and radar sites. Many of the systems we work on have units that weigh more than what the average maintenance person can lift. Some parts or units are not too heavy but their bulk or awkwardness causes a lifting hazard. If you're ever in this situation and judge that you can't safely lift a particular item, don't be a hero/heroine. Call for help.

Occasionally there will be a unit or part of a radar that presents a special lifting hazard. Some units must be lifted in or out of their normal location by only one person, due to equipment configuration. If you find yourself in these situations and you feel that you can lift the unit, be extremely careful. Before attempting to lift this type unit by yourself, talk to the equipment supervisor and obtain his or her permission. In these situations, be extremely careful to make a clean lift of the unit. There is the possibility that your hand or arm could get pinned under the lifted unit if your lift isn't done properly.

Cleaning Agents. Cleaning agents present a hazard to both the maintenance personnel and the equipment. Many cleaning agents can cause equipment damage if improperly applied or applied to the wrong parts. Your equipment technical order should prescribe the proper cleaning agent and action.

Personnel using cleaning agents should be aware of the agents hazard to living beings. Some agents give off a vapor that can cause breathing problems or even vision problems. Cleaning agents can also cause skin and eye irritations. Read cleaning agent labels prior to using for hazard warnings.

Congested Work Area. This subject area isn't often covered in safety books but, for this career field, it definitely presents a hazard. Some radar vans are as large as an average semitrailer while others are barely large enough for two or three people to fit inside. Radar sites are usually built in a compact configuration with the radars backed up to the site. Maintenance work areas serve as both work areas and storage areas for such things as test equipment. Offices are often cramped. Operations areas and control workcenters get congested because of the amount of people traffic. These conditions may not exist for all sites but it basically describes the average site. On sites manned by TDY personnel, the congestion is often worse. Radar crews that go on inobility are similar—cramped for space. The point of all these descriptions is congestion. Any organization that has to work in such congested areas will have hazards such as people running into each other and having to work around each other. Tripping hazards, such as open desk drawers or cabinet doors, are always present. Life on such sites isn't bad but personnel who work there must be aware that these congested areas pose hazards that can cause injuries. Add to all of this the pressure of inbound aircraft or a broken radar with people scurrying around and the hazards increase. Another situation that also adds to the congestion is crew change. Most sites are comfortably

congested with only one crew on site but when the relief crew comes in, things really get crowded. Remember, be aware of congestion hazards and do your part to prevent injuries.

Weather. As stated in earlier portions of this chapter, we work on radars; and those radars are located outside, exposed to the elements of weather. In the summer, you may have to work on a radar that is so hot that the unit you're replacing will burn your hand. The following winter, you may have to replace that same unit again and this time your bare hand may become frozen to the metal! In both cases, a hazard exists and must be taken into consideration before starting to work. Cold weather presents more hazards than hot weather. Some locations have weather so cold that the metal of the unit being worked on will break if improperly handled. Radar units with moving parts exposed to cold weather often freeze solid. Personnel that have to work outside during such cold weather conditions are exposed to multiple hazards. First, the hazards of frostbite or hypothermia present immediate dangers. Secondly, because of the cold, personnel must wear bulky clothing that restricts normal movements and causes work to be more difficult. As mentioned earlier in the height hazard section, working atop a radar is bad enough, but when the elements of cold and restrictive clothing are added, the hazards increase. Also, cold weather usually brings freezing rain or snow. All these extra hazards make working out on the radars very dangerous.

We are in the business of training and evaluating aircraft crews and that means that our radars must be operational when needed. The weather elements mentioned earlier related to cold but we also have to work in other adverse conditions such as rain. If a radar breaks, and the repair action requires us to go outside to complete the repair action, we must work in the rain as well. Any kind of moisture on working surfaces results in unsafe conditions for both footing and handling objects. Also, moisture getting into the equipment causes possible electrical hazards.

Whether the hazard is the heat, the cold, the wind or moisture, the mission has to be done. You, the maintenance person must be aware of these hazards and take them into consideration when you go out to do your work.

Vehicles. This area is going to be broken into two basic areas, SAC and TAC. Personnel working in SAC primarily work with General Services Administration (GSA) support vehicles such as crew vans, station wagons, and pickup trucks. These vehicles are mainly used to transport personnel, supplies, or parts between the support bases and the sites or when TDY, from the motels to the sites. Most are normal civilian type automobiles just like we drive ourselves. The hazards arise when someone must drive a vehicle that they're unfamiliar with and in unfamiliar environments. GSA vans are notorious for being hard to handle in crosswinds. Often, SAC personnel must drive in less than desirable weather conditions such as ice or snow. They also have to drive in areas of the country that have strong crosswinds. Add all these elements together and vehicular hazards become very important. Another area that SAC 303X3 personnel must be aware of is working around

semitrailers. Many of SAC's autotrack radars are mounted inside semitrailer vans or on flatbed trailers.

We 303X3 personnel must help tear down, pack, move, and set up these trailers. The hazard often arises when personnel have to go underneath or between trailers as the trailers are being moved into or out of place. Many of the trailers also have to be jacked up or down and blocked or unblocked. The danger of someone getting pinned by accident is obviously always there.

TAC 303X3 personnel face a whole different world when it comes to vehicles. TAC also uses GSA vehicles and the 303X3 personnel who drive them face similar hazards to those we discussed in the SAC area. In addition to the GSA vehicles, TAC 303X3 personnel must also work with a multitude of M-series vehicles. M-series vehicles are heavy-duty, all-terrain, military-style vehicles that include jeeps, 1/4 ton, 1/2 ton, and 1 1/4 ton pickup trucks, 2 1/2 ton "duce and a half" trucks, 40-50 ton cranes, 1/2 ton carryall vans, and modified personnel carriers (TRTG). Most of these vehicles are either four or six wheel drive vehicles. Towed pieces of equipment include 25-40 foot flatbed or "low-boy" trailers, mobilizers, and radar vans. Some of the radar vans weigh as much as 34 tons. All of these vehicles present hazards largely because their handling characteristics are so different from the civilian vehicles that everyone's used to driving. These vehicles are driven on both smooth road surfaces and off-road. The weather conditions also have extreme effects on how these vehicles handle. Weather elements such as rain, snow, and wind, along with the vehicle's size, cause driving these vehicles to be a problem. Units using these vehicles will train the drivers before allowing them to "solo" but the hazards still exist. One major problem encountered, when working with large vehicles, is backing. Assistants or spotters must accompany a driver to assist the driver in backing or even moving forward in close quarters.

Since so much of TAC's radar work is done out on scoring ranges, another set of problems arise. The 303X3 personnel driving these vehicles often have to do their own basic maintenance on their vehicles. Work such as "jump starting" another vehicle can cause serious accidents if not done properly. Changing a tire on one of these large vehicles can be hazardous.

As you can see, 303X3 personnel can encounter multiple hazards while using vehicles related to their jobs. You may be in TAC or in SAC as you're taking this CDC but the Air Force has this "thing" about moving people around. You may some day find yourself faced with one of the aforementioned vehicle hazards.

Travel. This area of hazards can be related to both on duty and off duty situations. Personnel in this career field, especially in SAC, find themselves having to travel TDY from their home unit to some assignment halfway across the country. Most units give their people the option of flying or driving to the TDY assignment, but many people drive. Often, the trip will be over 1,000 miles which presents the hazard of excessive driving hours. Add to this the possible weather hazards and the problems increase. Winter travel presents very dangerous situations such as icy roads, heavy snow, freezing temperatures, and high winds. It's not

unusual to run into areas of the country where all routes are closed. There's also the possibility of personnel becoming stranded out in the middle of nowhere.

Traveling in personal vehicles is often hazardous because of poorly maintained or prepared vehicles. Inexperienced drivers in winter driving also causes problems. Personnel traveling in military vehicles face the same problems in weather conditions. Military vehicles are usually fairly well maintained and the hazards should be less.

Winter driving hazards aren't the only hazards faced by 303X3 personnel. Traveling during heavy rains presents the hazards of poor vision, poor traction, possible flooding in low areas, and possible water damage to braking and ignition systems. Dry and hot weather presents the hazards of vehicles overheating or rupturing cooling systems. These hazards apply to both personal and military vehicles and should be taken into consideration.

Exercises (001):

1. If a radiation hazard exists on the roof of a radar you have to work on, what type sign should you expect to see just below the roof's edge?
2. What type hazard is present when a unit is removed from its equipment cabinet and placed on a workbench?
3. What safety hazard exists if you're on the ground and two of your coworkers are changing out a unit on the radar above you?
4. What causes the noise hazards found in a typical radar?
5. You have been assigned to clean a unit using cleaning agent X. What are the possible hazards involved?
6. What type hazard is caused by the night crew relieving the day crew?
7. If you were assigned to help move a maintenance trailer from one side of the site to another, what hazard would be most obvious?

1-2. Safety Precautions

Remember the old saying about "an ounce of prevention is worth a pound of cure?" In our business, those ounces of prevention pay very big dividends. As you saw in the previous section on safety hazards, there are some real dangers in our work environments. Personnel can't sit around worrying about these hazards because there's still a mission to complete. Personnel in the 303X3 career field must always be aware of the hazards surrounding them and take the appropriate safety precautions to prevent becoming a victim.

002. State the proper safety precautions for a given safety hazard.

Radiation. The best rule of thumb when it comes to radiation is to first identify the radiated area and second, stay away from that area unless it is declared safe. Know the radiated areas, always check the operating status of other radars around you before going out, and if you operate a dangerous radar, inform other assigned personnel before you transmit. Also, keep an eye on newly personnel, or visitors, and don't let them get into a radiated area by accident.

In the area of radioactive tubes, handle with extreme care and follow the prescribed directives for disposal and storage. If a tube is broken, use approved tools and methods to clean up the debris.

Electrical Shock. Precautions to prevent electrical shock can be categorized into two areas, mental and physical. On the mental side, you must always be mentally prepared to work on electrical equipment. This preparation consists of mentally being aware of what actions you are about to perform, what dangers exist, and what you're going to do if an electrical shock does happen. Many people get themselves into trouble by going into a situation and not concentrating on what they're doing. They get sloppy and they get shocked. Another mental precaution is to never work on activated electrical equipment without a safety observer. It seems so needless to have a safety observer there for some minor adjustment, but what happens if your hand slips while doing that alignment and it lands on a high voltage transformer?

The second area of safety precautions is the physical side. First, there's the proper preparation of the technician. Rings, watches, bracelets, wire-rimmed glasses or other conductive objects will not be worn in or near exposed electrical circuits. These precautions are taught to 303X3 personnel from day one. Any metallic or conductive object can draw an arc when brought close to a live electrical circuit and can thus cause an electrical shock. Also, as mentioned in the hazards section, working in close quarters can be dangerous. If you're wearing loose clothing or even a nonconductive object, that object or that piece of clothing can snag on something and pull you into an electrical hazard. The best precaution here is to remove the object or bind the clothing so that the snag factor is prevented or reduced.

Second, the proper grounding of electrical equipment can prevent electrical shocks. This includes both the equipment you are working on and any test equipment you must use. If you follow the technical order (TO) specifications, you should be okay. Remember also that some of the new microelectronic circuitry requires the technician to be grounded to prevent electrostatic discharge from your body into the circuitry. All grounds must be physically checked to ensure the safety of personnel and equipment.

Another physical precaution is the posting of safety signs. These signs identify possible safety hazards to everyone. They're simple to read and do prevent injuries. There are signs such as "Man on Roof" which are usually hung on the power panel and operating controls when personnel are on top of the radar. Probably the signs most used are the "Interlock Open" or the "Interlock Override" signs. Anytime a cabinet or drawer, that has interlocks, is opened, an "Interlock Open" or an "Interlock Override" sign must be posted. These signs inform you that the safety interlocks, that are supposed to kill the circuits' voltages if a drawer or cabinet is opened, have been overridden or bypassed and exposed voltage exists. There is a "Danger High Voltage" sign for exposed high voltage hazards. In the area around a rotating antenna, there's usually a "Danger, Rotating Antenna" sign. This sign alerts people to the danger of a rotating antenna that could knock them off the top of a radar or pin them if they get too close. There are other signs in addition to these, but you get the idea. If there's a danger or a hazard, post the appropriate sign so all personnel can see the danger.

Safety boards are a physical safety precaution that many people take for granted and often misuse. Safety boards have a collection of equipment that must be available to either prevent an accident or to be used in case of an accident. By misusing safety board equipment or "borrowing" it, a safety precaution has been bypassed.

In the area of working on equipment that has been removed from the main equipment, the best safety precaution is to ground or discharge everything. If in doubt, do it anyway. Also, follow TO directives to the letter when removing specific units and short or ground them as directed. That unit or component may look harmless but make sure first.

As you can see, safety precautions for working on electrical equipment are plentiful. As stated earlier, if you are mentally and physically prepared to work on electrical circuitry, the dangers are going to be held to the minimum. If you bypass a precaution, you may be the one paying the dues, and those dues can be life threatening.

Heights. The safety precautions in this area are usually already defined for us and written out for us to follow. If you must climb, first establish your balance at the new height. Second, establish in your mind the status of the footing or working surface. Is it wet, frozen, dry, narrow, or wide? Next, take your time and get yourself as comfortable as possible, both mentally and physically. Follow all prescribed safety guidelines such as safety harnesses or hard hats. Also, post the appropriate signs inside the radar informing others that someone is on the antenna. Here again is the matter of concentration. When you're working at any height above the normal walking

surface, your concentration level must be raised. Take into consideration such factors as strong wind, bulky clothing, restricted movements, and slower reactions in colder weather. Radiation hazards from other radars must also be considered. When handling tools or parts, remember that there may be personnel below you and they could be hurt if something is dropped. Plus, there's the possibility that the item could become damaged from the fall. If you're underneath someone working at heights, be alert for dropped or falling objects.

Remember, working at heights puts a person into unfamiliar surroundings. Safety precautions are designed to prevent accidents and to help you cope with these unfamiliar conditions.

Noise. The safety precautions for noise are rather simple. Noise hazard areas are supposed to be identified as such and when you have to be in one of these areas, use the proper hearing protectors. These hearing protectors are usually in two styles. The style most commonly used, in common use areas, is the cone style which covers each ear with a sound dampening cone. These are usually found on a designated board or location near the hazard area. The second style is the soft, individual ear plug type. Many units will have these specially made for the user. Other units may issue a soft, general use ear plug. In either case, ensure the plugs are properly inserted into the ears prior to entering the noise hazard area. Remember, know the noise hazard areas and then protect yourself.

Lifting. The Air Force has countless man-hours per year wasted or lost due to injuries caused by improper lifting techniques. The rules for lifting are simple. If an object is too heavy for you to lift, get some help. If you lift, do it properly, using the legs and arms, not the back. Squat with your legs slightly bent and your back as straight as possible. Grasp the object on opposing corners and draw it as close to your body as possible while straightening your legs. When standing, keep the load as close to your waist as you can. These precautions are designed for normal lifting.

Due to the configurations of our equipment, normal lifting is not always possible. On those occasions where an object must be lifted in a one-on-one situation (you and it) and you feel you can't do the job, see the supervisor and ask him or her for a replacement or some help. The precaution here is, if you can't perform the lift properly, don't try it. Many of these special one-on-one situations require that once a lift is started, it must be completed because there's no way to get the lifter any help once the action starts. Remember, if in doubt, get help.

Cleaning Agents. Toxic chemicals can cause death or severe injury. When using cleaning agents or solvents, do not breathe the fumes or allow the solvents to contact your skin or eyes. Use cleaning agents only in a well ventilated area away from heat or flames. Apply the cleaning agents with a brush and keep a fire extinguisher nearby. Always read the directions on the agent before starting use. Properly dispose of materials used with cleaning agents.

Congested Work Areas. The terms "neat" and "tidy" irritate some people but for the 303X3 career field, they are the rules that we must live by. Because of our congested work areas, the best precaution is to keep everything neat, tidy, and in its proper place. Objects left in walkways are

just asking to be tripped over. Another precaution is to never run in these close quarters. Personnel rapidly turning a corner, even at a fast walk, may cause an injury by knocking someone else down or knocking something out of someone's hand. That something may be a \$6,000 piece of test equipment. Slow down and save us all a group of problems. Close doors or drawers to desks and cabinets. Store brooms, mops, etc., in proper places.

Weather. As was mentioned earlier when the hazards were discussed, weather can cause our equipment to either burn or freeze us. In both of these situations, the precaution of using gloves would have probably eliminated either of these hazards. Many of our precautions relate to cold weather. The precautions for cold weather cover clothing, exposure, and conditions. Anytime the temperature starts getting down into the 30s or below, precautions should be taken because of the windchill involved. Extra clothing will prevent cold hazards to a point. Remember that these extra clothes also restrict your movements. When the temperatures get well below freezing, exposure starts to have effects on the human body. Frostbite is a common danger and too long an exposure in extremely low temperatures can cause frostbite and/or hypothermia. Also, precautions should be taken because cold slows a person's physical and mental capabilities and as a result of this, possible accidents are more likely. Cold weather also brings on a whole new set of surfaces to work on or with. These unusual circumstances require extra precautions when handling tools, radar parts, driving, and walking. Extra care should be taken especially in the driving and walking areas. The cold weather precautions are basically (1) dress properly, (2) be aware of the amount of time you're exposed to extreme cold, and (3) always be alert to the changing surface conditions.

Extremely hot weather presents us with the opposite extreme of weather hazards. Although most of our work is done in air-conditioned radar vans or work areas, there are the occasions where we must be out in the heat. Extreme heat causes the body to lose its water content and, if not replaced, can cause physical damage. The best precaution here is to drink plenty of water and occasionally come inside out of the heat. Also, know the symptoms of heat exhaustion or heat stroke and be alert for these symptoms in yourself and your coworkers. Sun screening products such as lotions can also aid in preventing skin damage.

Vehicles and Travel. The safety precautions for vehicles and travel are often just common sense with some extra precautions added for the uncommon situations. Probably the first precaution one should take is that of familiarization. As stated in the hazards section, people being placed in unfamiliar equipment and unfamiliar environments often result in vehicle accidents. Your unit's OJT program should take care of the equipment familiarization phase before you use a particular vehicle. The main thing is to become very comfortable with the vehicle. Learn how it handles and reacts, how it turns and backs, and even how long it takes to stop from given speeds. Second, the environment can be learned by riding as a passenger while observing and getting "the feel" of the vehicle. After a ride or two, you'll need to start driving

yourself. Hands-on experience is the only way you're going to learn. You should make sure these two precautions are taken before you attempt to "solo" a vehicle of any kind.

Once you're driving, there are other precautions you need to make routine. First is vehicle reliability. Just as you see pilots preflight their airplanes, you should always preflight your vehicle. Check fluid levels, belts, hoses, oil leaks, lights, and tires. Emergency equipment should also be checked. Once you're out on the road, you'll need to make rest stops and fuel stops. At these stops, do a visual check of your vehicle. Check for leaks, tire wear, and any possible overheating problems such as brakes. These precautions will help ensure that your vehicle stays reliable. If any defects are noted, hopefully they can be identified and corrected while the vehicle is sitting still and won't become a problem while you're traveling.

Another precaution is trip planning. Whether your trip is in a military vehicle or your personal car, plan your trip. If you must go from point A to point B, sit down and plan out the route. Plan for rest stops and fuel stops, taking into consideration the time of day you'll be at a given point. Many gas stations don't stay open all night and especially out West, they're often not too close to each other. Also while planning the trip, you must take the weather into consideration. Plan for possible detours or emergencies. Keep a map with you and have a close idea of where you are on the map at any given time. Be prepared for delays and the possibility of being stranded because of snow. These trip planning precautions can save you time and possibly save your life.

Driving conditions change as you take your vehicle down the road and precautions have to be revised to suit the situation. Weather conditions such as rain, fog, snow, and ice are driving conditions that everyone must face, but the personnel in the 303X3 career field get more than their share. Because a large percentage of our locations are in the winter climates, we see more winter driving conditions. We also have to go TDY into these conditions and have to function. Driving in rain, snow, and/or ice results in a loss of traction to our vehicle. Fog reduces vision. Add to these conditions winds, especially crosswinds, and we have some very unsafe conditions. Anytime you find yourself having to drive in these conditions, slow down. If conditions get too bad, stop. If conditions appear as if they might force you to stop, refer back to your map and try to figure out a potential stopping place to wait out the storm. Getting stranded or having your road (interstate highways too) closed is a common occurrence, especially in the Northwest where many of our sites are located. It is recommended that you always carry a "survival kit" in your vehicle during winter driving. The kit should have an extra blanket or two, a few large candles, small metal cups and plates, and a few chocolate bars. If stranded, these items could save your life until you're rescued. A candle will heat a car's inside area. Just remember to open a window slightly. And above all else, stay with your vehicle! Remember, it's better to be a little late than dead! These type precautions are a must for members of the 303X3 career field.

As stated in the hazards section, 303X3 personnel must move trailers and radar vans, either on site or across miles

of road from one location to another. Anytime a large vehicle such as a van is moved, at least one person, other than the driver, will be along. This is more of a necessity than a precaution. This extra person will perform precautionary jobs such as assisting the driver in getting a van or trailer into or out of close quarters. The driver should always use the assistant to ensure no damage is done to the equipment or other personnel. The driver, the assistant, and anyone else around the van or trailer should take the precaution of being extra alert as to what is going on. These trailers weigh tons and can not be stopped immediately. Always stay clear of a trailer as it's being moved and be careful not to get trapped or pinned into an area. Radar sites have to be moved in all kinds of weather and they're often located in open fields. Personnel working with or near moving radar trailers or vans should be alert to the possibility of a trailer or van slipping or sliding sideways. Once a trailer or van is located close to or on its spot, personnel have to crawl underneath the van to get it ready for leveling. Leveling requires that the van be jacked. Extra precautions should be taken to ensure that jacks and leveling blocks are stable and on solid ground before the jacking process starts. Occasionally, a van has to be raised several feet off the ground. Extra care and caution must be taken by personnel working underneath to ensure the trailer doesn't shift and fall. Also, be alert for situations that could pin, pinch, or cut off fingers, hands, or arms. Mental awareness is the best precaution anytime you work around any of these type vehicles.

TAC 303X3 personnel must also know the extra precautions required while working around the M-series vehicles. Because of their design characteristics, M-series vehicles present different hazards and different precautions must be taken. Jeeps, for instance, have a nasty habit of flipping if handled improperly. Extra care is needed in driving a truck while towing a mobilizer (a four-wheel, wagon-style creation) because mobilizers tend to wander. Similar precautions must be applied when driving a semitrailer and long bed trailers because of the extra length of the whole vehicle. Unit OJT will take care of most of these types of training but all 303X3 personnel should keep these precautions in mind.

All 303X3 personnel should be extremely careful when "jump starting" another vehicle. Follow the directives to the letter because batteries may explode if directives on "jump starting" are not followed.

The preceding precautions are only a few of the precautions required while working around vehicles and traveling. This section is intended to make you aware of precautions you can take to prevent injury or damage.

Exercises (002):

1. What safety precautions should be taken when working with tubes that contain radioactive materials?

2. What mental safety precautions should you take prior to working on any piece of electronic equipment?
3. What safety sign should be used if you're going inside a radar cabinet to align a power supply?
4. You walk into your maintenance van and your supervisor tells you to clean a particular unit that is there on your workbench. What should be your first safety precaution before handling the unit?
5. You have been assigned as safety observer to a coworker who must check the levels atop an AN/MPS-9 and you've never been up there before. There're no radiation hazards. What precaution should you take when you first reach the roof?
6. You are assigned to clean a unit using a toxic cleaning agent and you decide to do the work at the enclosed end of the maintenance van. What safety precaution has been bypassed?
7. You and a coworker are working outside in 5 degree weather and you reach out with a bare hand to turn a metallic handle. What safety precaution have you overlooked?

1-3. Rescue Techniques and Victim Care

As you've seen in the previous two sections, the 303X3 career field personnel must face a number of hazards in their day-to-day work. In most cases, if the precautions are followed, accidents or incidents will be prevented. In this section we'll discuss some of the things to do if an incident does occur and someone is injured.

003. State the proper rescue action(s) or proper victim care for a given injury.

Radiation Exposure. If someone is overexposed to radiation or is suspected of being overexposed to radiation, that individual should first be removed from the radiation source and then taken for medical evaluation and assistance. Most overexposures can not be immediately identified. Basically, overexposure to radiation causes the human body to become overheated, from the inside out! It might take an extended period of time for radiation to become evident. Normally the body tells the brain that area

X is in pain and the brain tells the body to remove the pained area from the source of the pain. Overexposure isn't that simple. Overexposure to radiation may result in damage to the areas of the body that have different levels of pain and as a result, damage can often be done before the body ever senses the pain. Because of this, solid evidence of overexposure is difficult to establish without the proper tools and training. If you think you've been overexposed to radiation, report it to your supervisor and seek medical attention. Once reported, a qualified team will come out and tests will have to be run to verify your exposure.

If an open wound occurs after exposure to radiation caused by broken radioactive tubes, let the wound bleed. Do not suck the wound with the mouth. Wash the wound with soapy water and flush with clean water. Seek medical assistance. If no wound occurred but surfaces became contaminated from the broken tube, clean the surfaces using protective equipment and then dispose of all contaminated materials in containers such as sealed plastic bags.

Electrical Shock Injuries. These type of injuries occur more often and are easier to identify. The victim of electrical shock is dependent upon you to give prompt first aid. The first thing to establish is what kind of shock occurred. Minor shocks are common occurrences in this field and usually require little or no medical attention. Care must be taken with minor electrical shocks because at times there is a delayed reaction to the shock. A person may incur a minor shock, comment about it by yelling "Ouch", and then appear as if nothing had happened. That person's safety observer should get the victim out of the equipment and make the victim sit down for a few minutes to be observed. Often times a delay ~~occurs~~ and some people have been known to pass out or throw up after a minor shock incident. Once it is observed that no definable injury has occurred, report it to the supervisor anyway.

In the case of a major electrical shock where the victim is obviously in danger, the observing person should shut off the voltage at once. If the voltage cannot be immediately shut off, free the victim from the source, remembering to protect yourself. To protect yourself, you should use any device available that is nonconductive such as the rope or cane from the safety board. If these items aren't immediately available, use your belt, or a long-sleeved shirt or coat. Do not touch the victim with your bare hands until the voltage is removed. Once the victim is removed, call for help and start first aid procedures.

Falls. Anybody that falls, from any height, has the instinct to grab on to something, trying to prevent the fall. Their efforts often result in stopping the fall while causing other damage such as torn muscles, strained joints, or broken bones. If their efforts don't prevent the fall, numerous injuries may result. If someone falls, call for help and then get to the victim immediately. Try to prevent their movements and check to see if they're breathing. Fall victims should not be moved until it is established that no damage is done. If the victim is unconscious and not breathing, carefully rearrange the victim's body to a position where cardiopulmonary resuscitation (CPR) can be

started. Remember that CPR must be continued until help arrives.

If the victim is conscious, attempt to keep him or her calm and still. Try to establish the damage and make the victim comfortable. Keep the victim warm and monitor for signs of shock.

If a fall victim must be transported by nonmedical personnel and there is suspected damage to the back or to internal organs, the victim should be strapped down to a hard surface such as a door or a piece of plywood, kept warm, and then transported. As we covered earlier in this chapter, our radars are often located away from towns or base support facilities. Some sites have medics but many don't, and that leaves a lot of the first aid up to us. The electrical shock injuries and the fall injuries are probably two of our biggest, most life threatening problems.

Cleaning Agent Injuries. Injuries caused by cleaning agents fall into two categories, those caused by the agent's vapor and those injuries caused by physical contact. In the case of a victim being overexposed to the vapors, get the victim out into the fresh air immediately. Vapors will cause headaches, dizziness, and possibly nausea and the fresh air will help some although the victim may feel the effects for a short time after the exposure. Once removed from the vapors, the victim should still be taken to the medical clinic for further evaluation, if needed.

Injuries caused by contact of a cleaning agent with a human body occur either externally or internally. When external contact has been made, attempt to flush the contacted area with fresh water and seek medical help immediately. Due to the different agents, the different forms of internal contact, and the different body reactions to each, it is impossible to cover this area in this CDC. Cleaning agent containers have handling instructions printed on the container along with first aid procedures. Follow these instructions as best you can and follow up with the victim obtaining medical attention.

Weather Injuries. In the 303X3 career field, most weather related injuries result from falls. If a victim slips and falls, treat these types of falls just as we discussed before. Many bones have been broken because of a fall while working on ice or snow.

Because many of our locations are in the colder climates and because we have to work outside on radars, 303X3 personnel often face the possibilities of hypothermia and frostbite. In most cases, the victims will have enough sense to come in and warm themselves before these injuries occur. But, as is always the case, there are going to be some specialists who become overexposed to the extreme cold and injure themselves. Frostbite causes numbness, and causes the skin, most commonly in fingers, toes, ears, and the nose, to become tinted with white or blue. Hypothermia happens when the body's internal temperature becomes too low (95°F or below). Symptoms of hypothermia also include confusion, disorientation, or drowsiness; lack of coordination and sluggishness; slurred speech and slow, shallow breathing. Frostbite and hypothermia can be treated by getting the victim into dry clothing and a warm bed, blankets, or sleeping bag immediately. Use warm towels, a heating pad, or a hot water bottle. All of these devices

should be warm to the touch, but not hot. Concentrate on the trunk of the body, the shoulders, chest, and stomach. Keep the feet raised to improve circulation of blood to the head. The victim may be given warm drinks but no alcohol, sedatives, or tranquilizers.

Hot weather hazards are not as likely as are the cold, but they too must be treated. Most heat related injuries happen just like the cold injuries, by overexposure. Personnel exposed to extreme heat must attempt to help themselves first by occasionally going inside to cool down or by just finding some shade. If victims become overheated, get them to some shade, have them drink fluids (preferably water), and fan them to help them cool. Seek additional medical assistance if a victim doesn't improve within a few minutes.

As you can see, weather hazards can cause serious damage. Hopefully the hazards will be avoided and you'll never have to assist a victim or be a victim, but in case you do have to assist, use the training the Air Force gives you. These first aid tips discussed in this section are intended to be the first line of aid. There are more detailed procedures available but they must be performed by personnel more qualified than we.

Other Injuries. In the preceding sections we have covered several areas that cover injuries caused by radiation, electrical shock, falls, cleaning agents, and weather. In this section we'll talk in general about some of the other injuries we may be faced with in our career field and in day-to-day life. Injuries caused by noise are, in most cases, undetectable. If you think you have incurred an injury caused by noise, schedule an appointment at the medical facility for hearing tests and evaluations.

Injuries caused by lifting are more detectable. The victim in this case should immediately seek medical attention because if the injury goes unattended, the injury can become worse.

Injuries that happen in congested work areas, vehicular work, and even travel can be in any form, from a bruised knee to loss of life or limb. In all of these situations, medical care should be sought. Minor cuts or scrapes can get infected and cause more problems if not treated properly and immediately. AFP 50-34, *Promotion Fitness Examination (PFE) Study Guide*, has information on the treatment of wounds, broken bones, and an explanation of the CPR process. Most airmen in your situation have not been exposed to this pamphlet but you'll be using it quite often later on. For the time being and for information related to this area of the text, we suggest that you review the first aid information therein.

Hopefully, the preceding sections have given you some ideas about this career field. The material contained is not intended to scare you away from the career field. We hope that you will "read and heed" this information because it might save a life—your life!

Exercises (003):

1. While handling a tube containing radioactive material, you drop and break it, cutting a finger. What action should you take concerning the cut?
2. What type device should be used to remove a coworker from a major electrical shock source?
3. How should you treat a fall victim if the victim is conscious?
4. What kind of liquids should be kept from a victim of hypothermia?
5. What Air Force pamphlet is a good common source of information for the treatment of wounds or broken bones?

Publications

AS AN AUTOMATIC tracking radar specialist, you may often feel that your work with Air Force publications and maintenance management forms and procedures are of little importance. However, the accuracy of forms and procedures are very important to the Air Force. Every radar specialist should know the current procedures to follow in performing and documenting maintenance actions.

2-1. Air Force Publications

Have you ever started to do a job without any idea of how to do it, where to start, or what you need to complete it? At this point you will need Air Force publications. They save you time and energy. Why should you stumble and fumble making up procedures that others have already worked out?

There are many types of Air Force publications. It is to your advantage to learn about these publications and how to use them. As a radar specialist, you will use technical order publications more often than you use standard publications (regulations and manuals).

Even so, you should become acquainted with the various types of Air Force publications. You should also become adept in the use of indexes and other basic references. This will help you to locate the information you need to perform the tasks in your work. In this chapter we shall first examine the types of Air Force standard publications. Then we will proceed toward your more immediate concern, a discussion of the Air Force technical order system.

004. Identify particular types of publications.

Types of Publications. Our Air Force publications are divided into two categories, departmental publications and field publications. Departmental publications apply to at least two or more major commands (MAJCOM), separate operating agencies (SOA) or direct reporting units (DRU). Usually, departmental publications originate in HQ USAF.

Field publications originate at MAJCOM or SOA levels, or below, and apply to all units under the control of the issuing headquarters. How does this apply to you? You need to know and understand who creates the guidelines that you have to work with and, by doing so, have a clearer picture of your mission. The field publications will be generated by your MAJCOM and will apply to those people working for or with that MAJCOM. On the other hand, departmental publications will be generated by HQ USAF and will apply to all commands. Such departmental publications would be AFR 35-10, *Dress and Personal*

Appearance of Air Force Personnel, AFR 39-6, *The Enlisted Force Organization*, and publications such as technical orders that can be used in any MAJCOM.

Exercises (004):

1. If the Tactical Air Command generated a regulation covering operations on one of its ranges, what type publication would this be?
2. Strategic Air Command's regulation on bomber crew evaluations is what type of publication?
3. What category of publications would apply to at least two major commands?

005. Identify categories of published materials.

Now that we've established who generates particular publications, let's take a look at the different categories of published materials.

Categories of Published Materials. The categories of publications cover every possible kind. They are divided into standard, specialized, periodical, one-time only pamphlets, non-Air Force publications, and other printed documents.

Standard publications. Standard publications are issued by the Secretary of the Air Force; Chief of Staff, USAF; commanders; and staff officials at all levels to announce policies, assign responsibilities, prescribe procedures, direct actions, and to inform people. Authorized types are regulations, manuals, operating instructions, supplements, pamphlets, visual aids, bulletins, and staff digests. Training materials are not standard publications.

Specialized publications. These publications provide information of a highly specialized nature that cannot be published in a standard publication (for example, the Technical Order System).

Periodicals. These are informally written magazines and newsletters, used to publish nondirective material needed by a unit to perform its mission.

One-time pamphlets. These include nondirective classified or unclassified pamphlets that are not subject to change or revisions, are not shown in an index, and usually are not numbered.

Non-Air Force publications. The Air Force uses other federal agencies' publications, such as the Department of Defense (DOD), Federal Aviation Administration (FAA), etc., when the publications apply or are of interest to Air Force units.

Printed documents. Certain documents are not considered to be publications, even though they are printed to meet distribution requirements. Some examples are plans, programs, histories, staff studies, statistical summaries, reports, training materials, and similar documents.

As you see there are all kinds of publications and as a member of the Air Force you'll be required to work with some of them. You may need to look up a question about leave policies. On another occasion you may need to obtain information such as a part number for a resistor that has burned out on your radar. In either of these examples, you'll need to have some idea as to which type publication to start looking into.

Exercises (005):

1. Under what category of published material would an FAA publication be identified?
2. Which category covers operating instructions?
3. Which category of publications is written in an informal style?

006. State how the index and numbering system for a particular publication works.

Because of the large number of Air Force publications, a method for identifying them quickly is needed. We'll cover the numbering systems and indexes of regulations, manuals, etc., separate from those of a technical order system.

Numbering Systems and Indexes. Because of their differences, the numbering systems and indexes for regulations, manuals, etc., will be covered first with technical orders following.

Regulations, etc. Regulations, manuals, and pamphlets have a dual numbering system to simplify reference and control. For example, consider AFR 35-3, *Service Dates and Dates of Ranks*. The first number, 35, is the basic number. It shows that the basic subject of the directive is military personnel. The second number, preceded by a dash (-3), indicates exactly what area of military personnel is covered. In this case, the specific title corresponding to the

second number, -3, is service dates. The numbers are assigned by the Director of Administrative Services HQ USAF. They identify the publication, and, with the title, help you locate the exact information required. It is simpler to refer to a publication by its specific title than by its subject matter.

The basic number is the same for related subjects throughout the different types of publications. For example, AFR 34-3, AFM 34-4, and AFP 34-1 all are in the personnel services areas. So each has the same basic number of 34. The second number of the AFR, AFM, and AFP tells what part of personnel services each area covers.

Supplements are identified with the basic publications which they supplement and are numbered in sequence; for example, ATC Supplement 1 to AFR 4-1, *Functions and Responsibilities of Administration*. Remember that every Air Force publication is given a number and title. This makes it possible to index and file all publications in an orderly fashion. This makes it simple for you to locate any publication quickly and easily.

The indexing of regulations, manuals, etc. can be found in the O-series Air Force regulations. AFR 0-2 gives you the numerical index of standard and recurring Air Force publications. AFR 0-9 gives you the numerical index for departmental forms. AFR 0-17 gives you the index of the Air Force Occupational Safety and Health (AFOSH) publications. These will be the most used O-series regulations and should make your work easier.

Technical orders. Technical orders (TO) are very similar to publications such as regulations or manuals when it comes to their numbering and indexing. The TO system is used by 303X3 personnel much more often than are the regulations or manuals. The next section will give you a detailed discussion of the TO system.

Exercises (006):

1. Air Force regulations, manuals, and pamphlets normally begin with a dual number (34-3, 35-10, etc.). What does the first number indicate and how is it used?
2. What does the second number indicate?

007. Specify the procedures for identifying technical orders.

Technical Order System. Personnel in the 303X3 career field maintain a variety of different Air Force systems. Radars, computers, communications equipment, and other associated systems all have to be maintained using TOs as the source for information. Autotrack personnel must know how to use Air Force TOs. Personnel must also understand that the TO system is published under the authority of the Secretary of the Air Force in accordance with AFR 8-2 *Air Force Technical Order System*. What this means to you is that directions found in a TO constitute a military order

issued in the name of the Chief of Staff, USAF. Compliance with Air Force technical orders is mandatory. The TO system was established as an official method of disseminating technical data, instructions, and safety procedures pertaining to the operation, installation, maintenance, and modification of Air Force systems. Technical publications are published and distributed by the Air Force Logistics Command (AFLC). Publications printed by other Department of Defense agencies for equipment are incorporated into the Air Force TO system. These may be printed and bound according to the specifications of the procuring agency. Numbers are assigned to them before they are listed in the pertinent technical order index. Although the Air Force TO system is authorized by and explained in AFR 8-2, a more detailed explanation of the system is covered in the 00-5 series of technical orders.

Technical order numbering system. TOs cover a large number of subjects. A good numbering and filing system is needed so that repair specialist can quickly locate information they need. Let's discuss the numbering of technical orders first.

A complete explanation of the numbering system is outlined in TO 00-5-18, USAF Technical Order Numbering System.

The basic task of TO numbering is to group similar TO data into categories, systems, series of equipment, and equipment subseries, by means of an identifying numeric or alphanumeric TO number.

Each category of TO data has a unique TO numbering pattern. Sufficient flexibility exists within the total numbering system to allow for expansion or contraction, within numbering parameters, yet maintaining standard application of numbering patterns within each category.

TO numbers are composed of groups, separated by dashes (-), and each group is further divided into parts. The number of parts within any group varies according to the TO data being numbered in a specific category. Each part of a group consist of one or more numeric or one or more alpha characters. The numbering patterns used in identifying TO data in each category are outlined in sections II through XLI of TO 00-5-18. We'll discuss one of these patterns later in this section.

The TO number has provisions for a total of seven groups for use in the numbering pattern. TO data is identified, in most categories, by using only the first three or four basic groups. The remaining groups are used primarily to extend the TO number to identify specific sections of sectionalized manuals/media; to identify supplemental manuals; and to identify supplement, checklist, or workcard sequence numbers.

Figure 2-1 is an example of a TO number used in this career field. As you can see, this TO number has only three groups, with the first group having three parts. The first part, the 31, identifies the TO category. Category 31 covers seven primary ground electronic equipment systems. To further identify this equipment, group 1 has a second part, the "P", which identifies the electronic equipment systems or major group. The "P" indicates radar equipment. Now we can see that we're talking about ground electronic, radar equipment. The third part of group 1 is one or more

numeric characters which identify an equipment series or major subgroup within a major group or system. The "2" here indicates "control." Put all the parts of group 1 together and you'll see that we're talking about electronic ground control, radar equipment. It should also be noted here that a new set of numbers are coming into the career field in the first part area of group 1. Because of all the new trainer equipment; you'll be seeing new TOs with the number "43" starting off the TO number. Many of our new TOs will read "TO 43D7-" which indicates that the TO is for simulator/training devices.

Group 2 of the TO number has both numeric and alpha characters. The first numeric part, in the case shown in figure 2-1, a "2", indicates the nomenclature of the equipment. In the old system for explaining this numeric character, a "2" indicated the nomenclature as being AN or Army/Navy. Today, the "2" is referring to the "Joint Electronics Type Designation System" or JETDS. In either case, this first numeric character indicates the type of nomenclature. The rest of group 2 is made up of letters that further explain the nomenclature. The first letter identifies the type of installation being used. Examples are:

- F - Ground, fixed.
- M - Ground, mobile.
- T - Ground, transportable.
- U - General, utility.
- V - Ground, vehicular.

The second letter identifies the type of equipment. Examples are:

- P - Radar.
- R - Radio.
- S - Special types, magnetic, etc., or a combination of types.

The last letter of the second group identifies the purpose of the equipment. Examples are:

- B - Bombing.
- C - Communications.
- G - Fire control or searchlight directing.
- Q - Special or a combination of purposes.
- R - Receiving, passive detecting.
- T - Transmitting.
- X - Identification and recognition.

Group 2 also has a second numeric character that follows the letters. This character indicates the type or design series of the equipment. The following examples show how these numbers can be changed or varied. Examples are:

- AN/MSQ2 verses AN/MSQ77.
- AN/TSQ81 verses AN/TSQ96.

In the first example, the "2" system and the "77" system were capable of doing like work but the "77," in this case, was a newer version. The same goes for the second example. The last numeric character does not always become larger for newer equipment.

Group 3 is the area where you'll be more concerned. All radar systems have their own set of TOs and once you're assigned, you'll become familiar with them. For instance, the TOs for AN/MSQ77 all start with

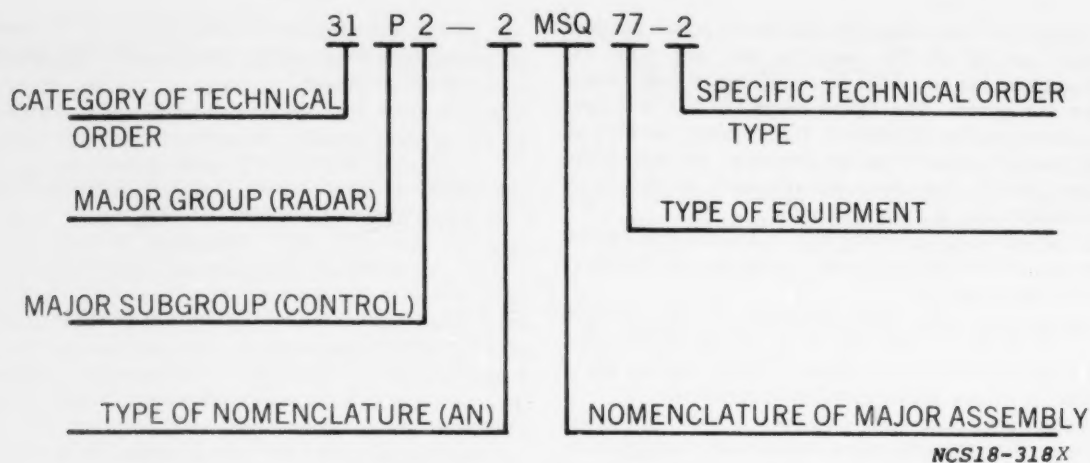


Figure 2-1. Breakdown of Technical Order Numbering System.

“31P2-2MSQ77-X”. Group 3 will fill in or identify the “X” part of the TO number. Group 3 characters will identify the type of manual/media or in other words, the specific technical order type. Since all the TOs for a particular radar would be too much to have in one book, the TO’s particular use or function is broken out and coded by numbers as in the following examples:

- Operating instructions: -1, -11, -21 through -491.
- Service or maintenance instructions: -2, -12, -22 through -492.
- Overhaul instructions and/or circuit diagrams: -3, -13, -33 through -493.
- Parts catalog: -4, -14, -44 through -494.
- Planning data and/or installation instructions: -5, -15, -55 through -495.
- Preventive maintenance instructions: -6, -16, -66 through -496.
- Standard installation instructions: -7, -17, -77 through -497.
- Inspection and testing procedures: -8, -18, -88 through -498.
- Alignment procedures: -9, -19, -99 through -499.
- Engineering and installation standards: -10, -20, -30, etc.
- Time compliance technical orders: -501 through -1000, then -1500 through -2000.

In the example shown back in figure 2-1, the TO numbers can now be completely identified as being the service instructions TO for the ground electronics radar, control equipment, Army/Navy (AN), family or nomenclature, Mobile (Ground) Special radar having a combination of purposes, series 77. It sure sounds easier when all you have to say is “31P2-2MSQ77-2”.

As we stated earlier, the TO number can be expanded to a total of seven groups. Your OJT trainer can explain the remaining groups to you if your equipment has TOs that break out to more than three groups.

Technical order indexing. Now that you see how a TO number is constructed, let’s see how we keep up with all these TOs, know if they’re current, and find them when we need them.

Let’s first look at how the numbering patterns are developed. Let’s use the TO number for the Index for General Technical Orders as an example. TO 0-1-02 breaks down with the first number, the “0”, indicating that this TO category is “0.” Category 0 covers indexes and cross reference tables. The second numerical character identifies the series of indexes. Examples of these series are:

- 0-1 TO Indexes.
- 0-2 Alphabetical Equipment List Cross-Reference.
- 0-4 Cross-Reference Tables.

The third and last numerical character identifies the specific publication indicator for a specific TO category. The “02” in our TO 0-1-02 example indicates that it is a general technical order. Other numerical characters that we may work with are:

- 22 Aerospace Vehicles.
- 31 Ground Electronic Equipment.
- 33 Test Equipment.
- 38 Non-Aeronautical Engines.
- 43 Simulator/Training Devices.
- 01 Technical Order Indexes.

You can use TO 0-1-01 to find which other TO index would list the TO you’re looking for. For instance, if you were looking for TOs that begin with “31P,” TO 0-1-01 would tell you to go to index TO 0-1-31-3. This TO (0-1-31-3) will list all TOs that start with “31P”. If you’re looking for the TOs applicable to an AN/MSQ77, TO 0-1-31-3 will have all TOs listed that work with the AN/MSQ77. This TO will also tell you what the current date of a TO is, if it has supplements or changes, or if it has been replaced.

The unit you'll be assigned to will have a person assigned to take care of all TOs used by that unit. This TO representative has an AFTO Form 110 file to keep control of the TO system. The AFTO Form 110 file will have information such as number of TOs required, number on hand, number required but not available, and their status (ordered or not). This person will also know which TOs are maintained or kept in each workcenter.

TO indexes today are being kept in a microfiche format. Your unit OJT trainer will have to train you on the use of the microfiche machine.

Changes, revisions, and supplements. It is the Air Force objective to ensure that related or interfacing technical orders are compatible at all times. This is done by use of changes, revisions, supplements, and appendixes.

Changes are issued when only parts of existing TOs are affected. The changed pages replace the corresponding numbered pages and all replaced pages must be removed from the TO. The list of affected pages will be on the reverse side of the new title page. Under the column headed "change number," the number of the change is listed, such as 1, 2, 3, etc. The 0 is used to denote original issue of a page, a blank page, or a group of original pages. A word of caution before filing: the complete change should be checked against the new listing to ensure completeness and accuracy. The basic date on the cover page of the change should match the basic date of the cover page being replaced.

Supplements are issued to augment or to change data in the basic TOs. This material is not adaptable for inclusion as individual change pages. Safety and operational supplements will be filed in front of the basic TOs. If you have an operational and a safety supplement for an individual TO, the safety supplement must be filed in front. Other supplements are on the basic title page.

Revisions are used to replace an existing TO. Normally the title page of the revision will have a statement such as, "This Publication Supersedes TO (TO number and date)."

Always remember, know what you're going to do before you go tearing out pages of any directive. Posting changes, supplements, or revisions can often cause the publication to end up with pages missing, wrong pages removed, wrong pages left in, change pages placed in the wrong area, and so on. It always helps to have someone else check the changes if time and manpower permits.

Exercises (007):

1. What technical order series gives a detailed explanation of the Air Force Technical Order System?
2. In the TO numbering system, what is the total number of groups or groupings allowed in a TO number?

3. In the second group of indicators in a TO number, what does the numeric character following the letters "MSQ" represent?
4. Which group of indicators in a TO number identifies the type manual or specific TO type?
5. What would be the TO number for an index TO on test equipment?

008. Given a hypothetical situation, identify the type of TO needed for that situation.

Types of technical orders. As you know, the automatic tracking radar field encompasses many varied and highly complex types of equipment. It would be virtually impossible for one to remember all the information necessary to maintain the equipment you may come in contact with in this career field. Learning to use the different categories of TOs properly will save you many hours. We will discuss separately the TOs that you will use the most in the performance of your duties.

The types of TOs authorized for issue are:

a. **Technical Manuals (TM).** The technical manuals contain the operation and maintenance instructions designed to meet the needs of personnel engaged or being trained in the operation, maintenance, service, overhaul, installation, and inspection of specific items of equipment and materials. TMs covering specific ground electronic equipment are published in separate manuals, which are discussed in the following paragraphs.

(1) Service manuals are a form of TMs that cover all the information necessary for the installation, operation, maintenance, calibration, and repair of equipment concerned. The following list identifies the five chapters that you'll find in a service manual.

Chapter 1 - General Information. This chapter gives description and purpose, leading particulars, and the equipment supplied with the system. Some examples are: Beam width, power requirements, range, transportability, tools and/or test equipment supplied, etc.

Chapter 2 - Installation. This chapter provides information on installation, planning, and logistics. Some examples are: Hardstand requirements, site accessibility, power availability, etc.

Chapter 3 - Operation. This chapter provides brief information on controls, indicators, and normal and emergency operating instructions.

Chapter 4 - Principles of operation. This chapter covers functional system operation and functional operation of electronic circuits.

Chapter 5 - Maintenance. This chapter describes the maintenance performed in the field or at the depot.

The technical information in this manual is written from the standpoint of a maintenance person with previous experience with related equipment. All basic theory is excluded from the explanation. Should basic theory be required, you should consult TO 31-1-141 series.

(2) Circuit and diagram manuals contain all circuits and diagrams, waveforms, and voltage-resistance charts for a specific type of equipment. This TM will be used extensively in troubleshooting radar equipment.

(3) Illustrated parts breakdown manuals contain a group assembly parts list of a system and a numerical index of the articles, assemblies, and subassemblies that can be assembled, reassembled, or replaced. It should list these items by the manufacturer's part number and, in some cases, the stock number. The illustrated parts breakdown will provide the information required for ordering parts.

b. Methods and Procedures Technical Orders (MPTO). An MPTO is a TO that establishes policies and provides information and instructions on maintenance management or administration, configuration management, and so forth. Examples are all 00-5 series, most 00-20-series, 00-25 series, and 00-35-series.

c. Time Compliance Technical Order (TCTO). A TCTO includes instructions for modifying equipment, performing or initiating special one-time inspections, and imposing temporary restrictions on aircraft flight, missile launch, or usage of airborne, ground communications-electronics equipment, and support equipment. Policies and procedures for management of the TCTO system are contained in TO 00-5-15.

d. Index (Type) TO. An index TO shows the status of all TOs and provides personnel with a means of selecting needed publications.

e. Abbreviated TOs. This is primarily a work simplification device, such as a checklist, inspection workcards, lubrication chart, sequence chart, or alignment manuals. Alignment manuals, like the ones we normally use, contain the information necessary for complete alignment and adjustment of the equipment. It does not include specialized maintenance or factory level alignment procedures, primarily because these are not usually performed by field personnel. These instructions are written to be readily understandable by 5-level maintenance personnel. It is assumed that the maintenance personnel are familiar with the operation of the test equipment required for the maintenance of the equipment. Preventive maintenance workcards are a set of simplified instructions, presented in a step-by-step fashion. They consist of performance routines and servicing routines, such as cleaning, oiling, and greasing of components. These workcards identify the tools necessary to complete the routine and the time required.

f. Preliminary TOs. These TOs are prepared in limited quantities to test and verify procedures against the first test or early production models of equipment. These TOs may be used for training purposes; however, they are not to be used for operation or maintenance by operating commands.

Exercises (008):

1. You have recently been assigned to a radar system

with which you're unfamiliar. What TO gives the guidance for operating the new system's controls?

2. What type manual would be needed if you have to trace a signal through a radar's circuit?
3. What kind of TOs are used with a test model radar?

009. State the purpose of a technical order improvement report.

Technical order deficiency reporting. The term "deficiency" denotes an error or defect which changes the meaning of instructions. It could also give insufficient information to adequately perform a task or function. (Example: misspelled words, typographical errors, and improper sequencing of pages.) An AFTO Form 22, Technical Order System Publication Improvement Report and Reply, is initiated by the person who discovers the deficiency. His or her supervisor checks that the deficiency is valid and important enough for submission. The deficiency report next goes to Quality Control for approval. Then it goes to the Air Force Logistics Command (AFLC) depot indicated in the storage and issue column of TO indexes. AFTO Forms 22 are submitted in one of three priorities: (1) Emergency; (2) Cover Letter; or (3) Routine. Before you submit the report, consult with Quality Control. They will advise and assist you.

AFLC takes action on emergency reports within 48 hours after receipt. On cover letter reports, action is taken within 40 days. Unless routine reports are disapproved, AFLC makes no reply to them. Changes to TOs are published within 240 days.

Each of us has the responsibility for reporting any TO deficiency to ensure that we have the best up-to-date TOs possible. Further information can be found in TO 00-5-1.

Exercises (009):

1. Why would you file a TO Deficiency Report?
2. What form is used to initiate a TO correction?

CEM Maintenance Management

YOU AND THOUSANDS of other Air Force members are involved in maintenance to keep our complete aerospace equipment ready for use. You are part of a worldwide maintenance program. About 37 percent of all personnel in the Air Force are in this program and consume about 40 percent of the fiscal budget. Air Force maintenance responsibilities include all aircraft, missiles, AGE, weapon systems, ground communications and electronics, simulators, trainers, and precision measurement—everything except ground vehicles and real estate. You can see, therefore, that a function of this magnitude demands streamlined management and strict attention to detail.

In this chapter we will describe the makeup of a maintenance management organization and emphasize the importance of providing the maintenance data collection system with accurate and exacting data. Without this detailed knowledge and an appreciation of the Air Force maintenance system, there would be chaos in all maintenance organizations.

While studying this chapter, you should remember that any organization must be flexible enough to meet changing needs. The organization of maintenance activities directed by command 66-X series regulations will be revised, when needed, to meet the demands of our changing times. Some of the details you study here may change in time, but if you understand the basic information, you will be well-equipped to adjust to these changes.

3-1. Functions of Chief of Maintenance

Maintenance organizations vary greatly because of the mission, assigned equipment, location, and size of each organization. Though shops performing similar jobs among the major commands differ in organizational structure, any maintenance organization needs certain elements. One of these elements is a chief of maintenance and his or her staff.

010. State the primary function of the chief of maintenance.

Let's assume you have been elevated to the position of chief of maintenance. You are at the highest level of operational control. What are the duties of your job? First, you are the executive manager of your maintenance organization with the centralized control and direction of all functions of the activity. The maintenance staff agencies assist you, acting in the name of the chief of maintenance

on those matters for which they have been given responsibility. In the maintenance manager concept (upon which the Air Force maintenance system is based), the chief of maintenance (you), through your staff functions, plan, control and schedule maintenance. For example, skilled mechanics with special equipment are sent out to do a highly technical job. Putting them where they are needed requires a system of scheduling, priority assignments, and dispatch and control action from a central agency—the chief of maintenance. We will discuss each staff agency individually so that you can grasp the general management concept and the special function of each agency. Understanding the basic responsibilities in your organizational structure is a necessary part of the training of each officer, enlisted member, and civilian in the Air Force.

As the chief of maintenance, you are a manager. You run the maintenance organization in accordance with policies and procedures outlined in command 66-X series regulations. You must apply the principles of leadership and management, and expect your supervisors to do the same. You and your staff must provide direction and guidance for all subordinates in the maintenance organization. This direction must comply with local and higher authority policies and instructions. You must be capable of estimating and programming facilities, equipment, manpower, and training requirements through study and analysis of the organization.

Exercises (010):

1. What is the overall function of the chief of maintenance?
2. How does the chief of maintenance fulfill his or her responsibilities?

3-2. Chief of Maintenance Staffing

Special staff elements consisting of Administration, Production Analysis, and Logistics Support are charged with the management support functions. These functions are not specifically related to the direct control of

maintenance production. The functions of the chief of maintenance, which are related to the direct control of maintenance production, will be done by Maintenance Control and Quality Control.

011. Identify staff functions under the Chief of Maintenance.

Administration. This staff function is the administrative center for the maintenance organization. Its duties include the preparation and maintenance of reports, correspondence, local maintenance operating instructions (MOIs), and the control of keypunch services. It is the focal point for all correspondence and reporting.

Production Analysis. Production Analysis is the primary management information source for the chief of maintenance. It operates as a data surveillance and statistical unit. Its overall objective is to improve the maintenance operation by examining various maintenance management output products and reports to identify trends that are developing. Raw data alone can be misleading and must be carefully analyzed by production analysis personnel before it is used by management.

Logistics Support. This staff function provides overall knowledge of new programs and their impact on existing maintenance resources to the chief of maintenance. In addition, it ensures that logistics support is on hand to meet the needs of the new program.

Maintenance Control. The maintenance control function plans, schedules, monitors, controls, and provides support for maintenance production. It determines and authorizes the expenditure of manpower and materiel within the maintenance activity. Maintenance Control has three subfunctions: Job Control, Materiel Control, and Plans and Scheduling.

Job control. Job control directs and coordinates the maintenance production effort. They control all maintenance actions that will cause an equipment status report (equipment is inoperative or limited). They control maintenance by issuing a unique job control number (JCN) for each action or job and by maintaining the status of the job as it proceeds. For each JCN issued, Job Control initiates a job status document (JSD). This form is used to document all information pertaining to the job: equipment outage time, nature of the problem, expected completion time, and, finally, the actions taken to correct the deficiency.

Materiel control. The people in Materiel Control ensure that the proper parts, tools, and equipment are available to the maintenance activities in the required quantities and at the proper time. They are the coordinating agency between Maintenance and Base Supply for the establishment of bench stocks, prepositioned spares, special levels, and supply point items. They also procure time compliance technical order (TCTO) kits.

Plans and scheduling. This function produces the maintenance plan and preventive maintenance inspection (PMI) schedule from known requirements and maintenance resource information. This plan guides the production effort toward efficient and high-quality maintenance by a schedule of predicted activity balanced against resources.

Plans and Scheduling also keeps maintenance historical data. It maintains and administers official historical records, completed JSDs, and TCTO records.

Quality Control. Quality Control is concerned with the quality of maintenance performed within the activity. It identifies and resolves problems through a monitoring program. Some of the specific responsibilities are:

- a. Technical publications - Set up and maintain technical orders, commercial manuals, and specialized publications.
- b. Materiel deficiency reporting - Analyze and report deficiencies to the chief of maintenance.
- c. Inspection - Determine the quality of maintenance done within the complex.
- d. Maintenance training - Be the focal point for maintenance training.
- e. Standardization and evaluation - Determine the competence of maintenance personnel through the maintenance standardization and evaluation program.

Maintenance standardization and evaluation program (MSEP). All personnel who perform maintenance are subject to MSEP, except contractor personnel, Air Force engineering technical services personnel, and technicians assigned to command-designated maintenance teams. The evaluator selects and assigns tasks to be performed and then rates the technician's performance on each task as satisfactory or unsatisfactory. Evaluations are conducted when new or modified equipment is installed, when a technician has failed a previous evaluation, or as directed by the chief of maintenance to check the adequacy of training.

Technical inspections. Quality Control performs technical inspections to evaluate the quality of maintenance performed on assigned equipment. They are also useful in identifying training deficiencies and potential problem areas.

Activity inspections. Quality Control inspects each management support function, staff function, and work center at least once a year. Some areas of coverage are:

- a. Procedural compliance with command 66-X series regulations and associated directives.
- b. Equipment status reporting and maintenance data collection.
- c. Compliance with prescribed safety rules and procedures.
- d. Supply discipline, bench stock management, and repairable processing.

Special inspections. Special inspections are requested by either the work center or maintenance supervisor, or are directed by the chief of maintenance, commander, or higher headquarters. Some of the uses of special inspections are:

- a. To investigate known or suspected management problems.
- b. To identify problem areas after unsatisfactory corrective action.
- c. To ensure upon initial issue that incoming precision measurement equipment meets TO configuration and physical serviceability requirements.

Exercises (011):

1. What unit is responsible for determining and authorizing the expenditure of manpower and materiel in the maintenance activity?
2. What part does the administration staff play in the maintenance management program?
3. What is the purpose of Production Analysis?
4. What function is the focal point for maintenance training?
5. Name the three sections that make up the maintenance control function.
6. What information does the logistics support function provide for the chief of maintenance?
7. State the purpose of Job Control.

3-3. Maintenance Data Collection System

The maintenance data collection system provides a way to record production credit for all tasks that use direct labor. This record is maintained on AFTO Form 349, Maintenance Data Collection Record. The first use of the information compiled by this system is for base-level management within the chief of maintenance complex. This information is also used at intermediate and major command headquarters. This system is continuously becoming of greater importance to the Air Force. The same recorded elements of data used by base-level management are used extensively throughout the Air Force Logistics Command (AFLC) for many purposes. Some of the specific uses by AFLC are:

- Analysis of each autotrack radar system for those items that have high failure rates and that are high consumers of man-hours.
- Identification of unsatisfactory items and substantiation for product improvement actions.
- Analysis of established inspection requirements and a basis for adjusting inspection criteria.
- Analysis and adjustment of the component time-change cycles.

- Analysis of component/item data to screen out unsatisfactory units.
- Analysis of the not-reparable-this-station (NRTS) listing.
- Computation of spares requirements based on usage.

012. State your responsibility in the production of valuable maintenance data.

Responsibility. How do you fit in the picture and what can you do to help the system work? Every time you work on the radar equipment in your unit, you enter what you have done on an AFTO Form 349. Summaries and computer runs are based upon the information you entered on the AFTO Form 349. So you see that the intelligence that scores of people will pick up from maintenance summaries depends entirely upon you and other workers who are maintaining equipment. The input items on the 349s identify the work required, the work done, the activity doing the work, the end item identification, why the work was required, when the requirement was discovered, the operating time, how many hours the work took, the persons who did the work, and many other essential facts.

Coding procedures are employed in this system so that the information can be processed through punchcard accounting machines and computers to produce summary reports and analysis products. Every prescribed form used in the system has space for specific coded information about the work being performed. The codes are alpha or numeric characters that represent standardized conditions, actions, and systems. A limited capability has been provided for the major command or local authority to collect additional data peculiar to its need. These codes make it possible to reduce extensive descriptive narratives to a number of short code symbols which can be "read" by accounting machines.

We already mentioned that you code your own forms. You must refer to the work unit code manuals and other sources to determine the proper codes. The job supervisor and the work center supervisor are responsible for making certain that all maintenance data forms are complete and accurately coded. The increasing use of this information in all elements of the Air Force makes it mandatory that supervisors ensure accurate recording. Incomplete or inaccurate maintenance data will result in erroneous manning, equipping, budgeting, recording, and requisitioning at higher levels of command.

The information is recorded on the forms; then it is punched into cards, either in the maintenance complex or at statistical services, depending upon how local keypunching facilities have been allocated. These cards are then mechanically processed periodically by statistical services to produce reports for use in the management of the maintenance function.

It is very important that the codes entered on the maintenance forms be accurate and clearly written so that the keypunch operators can read and enter them into the punchcards correctly. The reports produced are significant only if the cards are accurate.

Some of the terms that we use in the remainder of this chapter may be new to you. Since they appear from time to time in instructions in TOs as well as command 66-X series regulations, you should become familiar with these terms because they directly affect the maintenance activity. One term is "unit of work." A unit of work is a job that has a definite beginning and end. The fixing of each malfunction is considered to be a unit of work. A second term is "time change," used in reference to certain components on equipment. These time change components have a fixed life expectancy of a definite number of hours of operation, or a definite time period, or a fixed number of cycles of operation. A third term is "time significant." This term must not be confused with time change. A time-significant item is an item about which a study is being made to determine its life expectancy. A fourth term is "serially controlled." AFLC is concerned with the extent of modification of certain items. Therefore, AFLC demands reports on the operating time, modification, and repair of these items by individual item serial number. This information is reported when these items are removed from the equipment. The items on which these reports are made are called *serially controlled* items. Information concerning maintenance actions must be recorded "somewhere" for statistical services to receive the information it requires. The "somewhere" is on the AFTO Form 349.

Exercises (012):

1. State your chief responsibility in the production of maintenance information.

2. What is meant by the term "unit of work?"

3. To what does "time change" refer?

4. Describe a "time-significant" item.

5. What are "serially controlled" items?

013. Identify the correct information for selected blocks of an AFTO Form 349.

AFTO Form 349, Maintenance Data Collection Record. This form contains 30 blocks, some of which are divided into a number of smaller sections. Figures 3-1A and B show the AFTO Form 349. Because of the varied types of equipment used by the Air Force, the recording procedures cannot be identical. Standard recording procedures are prescribed to the extent that it is practical. The 00-20-2 series of technical orders contain the detailed instructions on the blocks to be filled out by each maintenance section.

To get a clear understanding of each block, we will discuss the general information to be entered, omitting the conditions under which it may be required. This you will learn through actual work experience with the forms.

MAINTENANCE DATA COLLECTION RECORD															OMB NO. 21-80227		
1. JOB CONTROL NO.		2. WORKCENTER		3. I.D. NO./SERIAL NO.		4. MDS		5. SRD		6. TIME		7. PRI		8. SORTIE NO.		9. LOCATION	
10. ENG. TIME		11. ENGINE I.D.		12. INST. ENG. TIME		13. INST. ENG. I.D.		14.		15.		16.		17. TIME SPC. RPT.		18. JOB STD.	
19. FSC		20. PART NUMBER		21. SER. NO./OPER. TIME		22. TAG NO.		23. INST. ITEM PART NO.		24. SERIAL NUMBER		25. OPER. TIME					
ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP HOUR	J DAY	K CREW SIZE	L CAT LAB	M CMD ACT ID	N SCH CODE	O AFSC/EMPLOYEE NUMBER		
1																	
2																	
3																	
4																	
5																	
26. DISCREPANCY																	
27. CORRECTIVE ACTION																	
																28. RECORDS ACTION	

AFTO FORM 349
JAN 81

PREVIOUS EDITION WILL BE USED.

U.S. GOVERNMENT PRINTING OFFICE: 1981-277-112

NCSB-751

Figure 3-1A. AFTO Form 349 (Front).

NCS8-750

22

Remember that the 00-20-2 series of technical orders are the governing directives.

The job control number that you enter on the AFTO Form 349 is assigned by Job Control. If several work centers participate in the same repair action, all actions taken are considered part of the job and carry the same job control number.

The work center block always contains the work center of the individual performing the work. If two work centers are involved in this action, two forms are required, one for each work center. The work-center designator is a standard 5-digit USAF work-center code established under the provisions of command 66-X series regulations.

The ID/serial number entry (block 3) on the 349 is a 6-digit number that identifies a specific type of equipment. If no 6-digit number is established, enter the end item serial number in block 3 and the mission, design, and series (MDS) in block 4. Also, enter the applicable SRD (standard reporting designator) code in block 5, and complete column L. The SRD code is found in the 00-20-2 series technical orders. Fill out the MDS block with the end item joint electronics-type designator (JETD) of the equipment, excluding the AN prefix. For equipment not assigned a JETD, and for all COMSEC and cryptologic equipment, enter the end item work unit code (WUC) preceded with two zeros. Column L, command account ID, is a two-position command code of the owning command for AFR 300-4, Volume 2, *Classified Data Elements and Codes*, for classified or Volume 3, *Air Force Data Dictionary (Microfiche)*, for unclassified.

An entry is required in block 6, Time, only for removal and replacement of items identified by an asterisk in the WUC manual. When applicable, enter the equipment time to the nearest whole hour, or the number of cycles or calendar time from the applicable documents on which time or cycles are maintained. Essentially, what we're talking about here is documentation of time-significant and time-change items.

The priority of work is entered in block 7 when the repair specialist has to be dispatched. No entry is required in block 8.

The only time that an entry is made in block 9, Location, is when the AFTO Form 349 is used as a dispatch form. If you are dispatched to perform maintenance, enter in this block the actual location where the work is performed.

Blocks 10 through 13 are not used for shop documentation. Blocks 14 and 15 are used at the discretion of local management.

Block 16 has been provided for a tenant support special-activities identifier. Its use is optional. If used, you enter the locally developed two-character (alpha or numeric) code that identifies support for nonreporting work centers or for special-activities/projects. Using this block is the only method of identifying those hours expended by a host performing support work for equipment assigned to other activities.

No entry is required in block 17, Time Specialist Required, unless the AFTO Form 349 is used as a dispatch form. Likewise, an entry in block 18, Job Standard, is required only if the form is used as a dispatch form. If the form is used to dispatch a specialist to perform

maintenance, the standard/average time required to perform this job is entered in block 18. If no job standard has been established, the estimated time required to complete the job is entered.

In block 19, you are required to enter the Federal Supply Classification (FSC) code for the item being removed for off-equipment work.

When off-equipment (shop) work is performed, block 20, Part Number, must have an entry. Normally, this entry is the part number of the item on which work is being performed. You must give special care to recording part numbers. Omissions, improper positioning of dashes or slashes, inclusion of dashes or slashes when not applicable, incorrect recording of digits, and omission of assigned modification dash numbers cause an unwarranted shredout of data for like items in base level and AFLC products. Exceptions to part number reporting and specific instructions for entries required in block 20 are:

a. The first preference for the block 20 entry is the manufacturer's part number for the component or complete assembly as it appears on the data plate. If the item does not have a data plate, get the item part number from the parts catalog.

b. If a complete assembly consists of subassemblies with separate data plates, enter the part number from the data plate of the complete assembly in block 20. If no data plate for the complete assembly is provided, enter the part number of the primary subassembly in block 20 to reflect reporting action against the complete assembly.

c. For those items that do not have part numbers, enter the NIIN (last seven digits of the national stock number) in block 20. Enter NSL (not stocklisted) in block 20 for locally manufactured items that are not stocklisted.

Block 21, Serial Number/Operating Time, is used for two different entries, serially controlled items and elapsed-time and time-change items. For a serially controlled item that is removed or being modified, enter the serial number of the item. If the serial number exceeds ten positions, enter only the last ten positions. When the serial number is entered as the identifying number, line out the Oper Time portion of the title to show that the entry is a serial number.

An entry in block 22, Tag No., is required when a serially controlled or time-change item is removed. If installation is done separately from removal, a suspense copy AFTO Form 349 is created. The original job control number is entered in block 1, and the last three digits of the AFTO form 350 tag number are entered in block 22 of the suspense AFTO Form 349.

When serially controlled items or time-change items are being installed, enter the part number of the item in block 23, Inst. Item Part No. Enter the serial number of the installed item in block 24, Serial Number. In block 25, Oper Time, enter the previous operating time of the item being installed. You can obtain the information for blocks 23, 24, and 25 from blocks 11, 12, and 8 respectively, from the AFTO Form 350 that is attached to the item being installed.

The center portion of AFTO Form 349 is divided into five horizontal action lines (1 through 5) and into 15 vertical columns (A through N). These lines and columns

permit you to record up to five maintenance actions on a single form, thus reducing the number of forms on which basic identification information must be recorded. If one of the maintenance actions recorded on lines 1 through 5 involves a discrepancy that requires bit-and-piece replacement nonreparable/nonrecoverable items, the identification of the component is recorded in block 29 (reverse side of AFTO Form 349).

Exercises (013):

1. When is an entry required in block 6 of AFTO Form 349?
2. When is an entry required in block 17 of AFTO Form 349?
3. What is the first precedence entry for block 20 of AFTO Form 349?
4. When is the serial number entered in block 21 of AFTO Form 349?
5. What information is entered in block 22 of AFTO Form 349?

014. Identify the correct information for specified blocks of an AFTO Form 350.

AFTO Form 350, Reparable Item Processing Tag. This form is required on components removed from end items and on subassemblies removed from components that require separate shop processing.

The AFTO Form 350, shown in figure 3-2, identifies the origin of the part. It also contains key data elements needed to document shop actions on a shop-generated AFTO Form 349. The AFTO Form 350 is also used as an off-base identification tag when not-reparable-this-station (NRTS) action is taken. It is a two-part form. Part I is the actual processing document and Part II is the reparable processing center (RPC) scheduler's control document.

The maintenance person who removes the component from the radar unit initiates the AFTO Form 350. Blocks 1 through 14 can be filled out with AFTO Form 349 information, such as the job control number, serial number

of unit, when discovered, how malfunctioned, part number, and discrepancy.

Block 15 is used for a brief description of the work done on the part, if the item was made serviceable. If the item is not reparable at your station, stamp NRTS and include the NRTS code in this block. If you use NRTS code 1, you must give the authority for declaring the item NRTS.

Part II of the front side of AFTO Form 350 is completed by Production Control/RPC, and detached and retained by that function as a record copy until the item is returned from the repair shop. The entries required on this side are merely copied from similar entries on the top front side of the form. Blocks 20 and 22 are the exception. When the repair is completed by the shop or the item is declared NRTS, the Action Taken code from column D of AFTO Form 349 is entered in block 20. Block 22, RPC Use Only, is for local use.

The back side of AFTO Form 350 contains more spaces; some will concern you; others are of no interest to you as a specialist.

Let us cover the first four blocks. The national stock number is entered in block 23. When a component is determined to be in NRTS status, the base stock record account number (SRAN) code is recorded in Block 24 by the shop concerned or RPC. Block 25 is for Supply only, and block 26, Serviceable, is used by the agency responsible for returning the item to a serviceable status. A stamp or signature and a dated entry are acceptable.

Entries are not required in block 27, Condemned. The item will be tagged with a DD Form 1577-1, Unserviceable (Condemned) Label—Materiel, Block 28, Supply Inspector's Stamp, is reserved for Supply use only.

The person who removed the component from the end item (initiator) enters in block 29 the date he or she removed the component. The reparable processing center production scheduler is responsible for making the entries in block 29, Base Repair Cycle Data. This is on the back side of Part II of AFTO Form 350. These entries show the date the item was received by RPC and indicate status changes for the unit. Example: To Shop, To Await Parts (AWP); To Awaiting Maintenance (AWM) (with corresponding dates). Dating makes possible the computation of "AWM time."

Part II of the AFTO Form 350 tag is more important than most maintenance personnel realize. This piece of the AFTO Form 350 tag is used by RPC to collate data on equipment usage. For example, if a particular item is repaired or worked on three different times in a certain time period, RPC should take steps to have another "like" item kept on base in Supply. If Part II of the AFTO Form 350 tag is used properly, you should have an extra component kept in Supply for each item that has shown up as a high-use item. You could have an entire radar set, in pieces, kept on base. AFTO Form 350 tags show Supply where the equipment usage is, and if you need something often enough to justify the expense of procurement and storage, the supply system will get it for you.

As you get experience with this form, as with AFTO Form 349, you will learn more about its use and the entries required.

AFTO FORM 350
OCT 82

PREVIOUS EDITION
WILL BE USED

OMB NO 0701-0014

REPARABLE ITEM PROCESSING TAG

1. JOB CONTROL NO.	2. ID / SERIAL NO.	3. TM	3A. SRD	4. WHEN DISC.
5. HOW MAI	6. MODS	7. WORK UNIT CODE	8. ITEM OPER TIME	9. QTY
10. FSC	11. PART NUMBER			
12. SERIAL NUMBER		13. SUPPLY DOCUMENT NUMBER		
14. DISCREPANCY				
15. SHOP USE ONLY				
15A. CMD / ACT ID		15B. SHOP ACTION TAKEN		
TAG NO. 222371		AFTO 350 PT. I		
16. SUPPLY DOCUMENT NUMBER				
17. NOMENCLATURE				
18. PART NUMBER		18A. WORK UNIT CODE		
19. NSN				
20. ACTION TAKEN	21. QTY.	22. RPC USE ONLY		
TAG NO. 222371		AFTO 350 PT. II		

FRONT

★ GPO 661-800

WARNING
Unauthorized persons removing, defacing, or destroying this tag (or what) may be subject to a fine of not more than \$1,000 or imprisonment for not more than one year or both.
(18 USC 1 361)

REPAIR CYCLE DATA

23. NSN	24. SRAN CODE
25. TRANSPORTATION CONTROL NUMBER	
STATUS CHANGED TO	
26. SERVICEABLE	
27. CONDEMNED	
28. SUPPLY INSPECTOR'S STAMP	
29. BASE REPAIR CYCLE DATA	
DATE REMOVED	REC'D BY RPC
TO:	
TO:	
TO:	
TO:	
TO:	
DATE COMPLETED	

BACK

NEO13-489

Figure 3-2. AFTO Form 350.

Exercises (014):

1. Where do you obtain the information for blocks 1 through 14 on AFTO Form 350?
2. What entry is made in block 15 of AFTO Form 350?
3. Who is responsible for Part II of AFTO Form 350?
4. Who is responsible for the entry in block 26 of AFTO Form 350?
5. What does an entry of AWP in block 29 mean?

015. Identify selected terms that apply to processing and controlling equipment.

Processing and Controlling Equipment. Materiel Control has the responsibility for processing and controlling the parts, tools, and equipment that are needed by the maintenance activity. It must see that the required quantities of tools, parts, and equipment are available at the proper time. Without this function of maintenance management, individual technicians would lose a great deal of time trying to locate available items when they need them. The basic requirement for fulfilling these responsibilities is the ability to forecast the supply requirements of each maintenance activity with effective followup procedures to ensure that plans and schedules will not fail or be delayed for lack of supplies.

Materiel Control keeps all maintenance activities informed of the overall supply situation, recommends improvements of supply support, and recommends equipment redistribution when inequalities exist. The efforts of this activity must be continually directed toward increasing the maintenance output. If material cannot be supplied through normal channels, Materiel Control, working with Supply, investigates all possible sources for the needed items.

Materiel Control makes a continuing study of supply action to discover the factors that cause supply delays. Each delay must be analyzed and brought to the attention of the appropriate personnel for correction. It must make every effort to provide the required items at the work location at the proper time without loss of maintenance and man-hours.

Critical items. Critical item lists are maintained by Base Supply in coordination with the Materiel Control. These lists are reviewed periodically to aid Supply in determining supply and repair action. Critical item lists are used to keep

both Production Control and Supply informed about the status of critical items in the repair cycle. Critical items are designated by AFLC, by the major command, or by the local chief of supply. Also, any item creating two or more MICAP (mission capable supply) reportable conditions or two or more cannibalizations in a 30-day period should be considered by the critical item monitor for inclusion in the base critical item listing.

A critical item is identified by the word "Critical" appearing on the issue document from Supply. Any item identified as critical must be delivered promptly to Production Control when it is removed from the end item. Production Control is then responsible for entering the item into the repair cycle with the proper priority.

Repair cycle assets. Another category of supply property is the repair cycle assets. This category includes all equipment that requires bench checking and/or repair. Equipment that is bench checked and found serviceable or is repaired and restored to serviceable condition is stored in supply warehouses or at other suitable supply points, as determined by Base Supply in coordination with Materiel Control. The primary purpose of these supply points, managed by Base Supply, is to facilitate maintenance support. Not all items in the repair cycle are stocked at these strategically located supply points. It is not entirely up to Supply to decide what items are to be stocked here. Materiel Control assists Supply in determining the line items and quantities needed and frequency of need of a particular item, as indicated by past usage. Maintenance personnel normally request (or order) repair cycle asset items directly from Supply by telephone, radio, or document (request for issue form) as dictated by the urgency of the requirements.

The term "preplanned requirements" is applied to items, other than bench stocks, that are required for replacement during forthcoming periodic inspections. Normally, such items include those that are directed by technical orders for a time change plus those known to require replacement but carried forward to the periodic inspection.

Preplanned requirements serve a two-fold purpose in the overall support program. First, a standardized system is provided for forecasting a part of the maintenance requirements. This lets Supply personnel review their available assets to determine whether they have sufficient stock to meet a known requirement. Second, Supply personnel can submit special requisitions to depots well in advance of needs.

Time-change requirements. The records activity ascertains the time-change requirements and refers such information to Materiel Control. Materiel Control consolidates these time-change requirements and furnishes the data to Supply. It also determines the physical availability of items if such information must be considered in maintenance planning and scheduling.

The items and quantities needed for time change are verified by the records activity representative. This verification is particularly important to ensure that items, previously listed for change but not replaced because of failure, are removed from the list.

Upon verification of these requirements, Materiel Control determines the availability of the items and notifies

the maintenance chief so that replacement items can be placed on the inspection sequence chart.

Cannibalization. Another responsibility of Materiel Control is keeping records of cannibalization. Cannibalization is the removal of a specific assembly, subassembly, or component from one equipment end item for installation on another equipment end item. Cannibalization is authorized to meet priority requirements, and only then with an obligation to replace the removed item.

When cannibalization is necessary, Job Control will request approval from the maintenance control supervisor or representative. Approved cannibalization actions will be directed and controlled by Job Control, and documented by Materiel Control and the work center. Materiel Control uses an AF Form 2414, Verification Worksheet, while the work center uses the AFTO Form 349.

Exercises (015):

1. Give the two reasons for listing items on the critical item list?
2. What types of supply property are considered to be repair cycle assets?
3. What are preplanned requirements?

016. Identify the proper condition tag to be used in a given situation.

Condition Tags. Often, when a unit or piece of equipment is removed from use, it also is required to have further identification concerning its status. Figure 3-3 has examples of three of the more commonly used tags for showing equipment status.

In addition to the requirement for the use of the AFTO Form 350 for maintenance processing of items that require off-equipment or shop actions, DD forms are required to indicate the condition status of items that are processed to supply activities for return to serviceable stock, for forwarding to off-base repair activities, or for other disposition action.

The condition tags are in color for ease of status recognition. The yellow tag, DD Form 1574, indicates that the item is in serviceable condition. The green tag, DD Form 1577-2, indicates that the item is unserviceable but is repairable. The red tag, DD Form 1577, is used to indicate that the item is unserviceable and nonrepairable. Red tagged items will be returned to Supply for disposition. Once any of these tags is attached to an item, it will not be removed except when the condition status of the item changes (note warning on tags).

For all items returned to Supply, the maintenance activity responsible for condition status determination will prepare the applicable DD Forms that are used as tags and labels to identify the item condition. These forms are filled out in conjunction with Materiel Control, and they have to be approved by a qualified inspector.

Exercises (016):

1. What condition tag would be attached to a track-range computer with a broken gear?
2. Who must approve a condition tag?

3-4. Materiel Deficiency Reporting System

No system is perfect. We are all familiar with the recall of automobiles to correct their deficiencies. The Air Force is no different. From time to time, a piece of equipment is found to have contributed to an accident or incident or created a safety hazard. Some of these items are caught through an analysis of the maintenance data collection system. The Air Force also depends upon each individual to report materiel deficiencies. The responsibility for clearance and control of materiel deficiency reports is assigned to Quality Control. If you ever have to make out one of these reports, check TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System*, to make sure you have the latest information. Also, be sure to check with your quality control section for up-to-date advice on materiel deficiency reporting (MDR). Let's see what type of reports are available and how they are defined.

017. For a given situation, state which type deficiency report should be used if any.

Types of Reports. Occasionally, deficiencies develop that require immediate reporting so that (1) the same deficiencies can be corrected on like equipment at other installations and (2) improvements can be made in design, test, and modification programs. Details for reporting materiel deficiencies under this system are in TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System*. To report materiel deficiencies, two reporting categories are available with three possible reports. These are the Category I Report, the Repeat Category I Report, and the Category II Report.

Category I report. This is a report of emergency conditions of a safety nature on all types of equipment. The four emergency conditions are:

- (1) Accident or incident.
- (2) Nuclear safety deficiency.
- (3) Critical safety deficiency.
- (4) Explosive safety deficiency.

Accident or incident. This is an unexpected event that does damage or could cause damage to persons or property.

WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than \$1,000 or imprisonment for not more than one year or both. (18 USC 1361)	FSN, PART NO. AND ITEM DESCRIPTION		SERVICEABLE TAG - MATERIEL	
			NEXT INSPECTION DUE/AGE DATE	CONDITION CODE
			INSPECTION ACTIVITY	
	SERIAL NUMBER/LOT NUMBER	UNIT OF ISSUE	INSPECTOR'S NAME OR STAMP AND DATE	
	CONTRACT OR PURCHASE ORDER NO.	QUANTITY		
REMARKS				

REPLACES AF FORM 30B, WHICH MAY BE USED IN THE USAF.

DD FORM 1574, 1 OCT 66

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WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than \$1,000 or imprisonment for not more than one year or both. (18 USC 1361)	FSN, PART NO. AND ITEM DESCRIPTION		UNSERVICEABLE (REPARABLE) TAG - MATERIEL	
			INSPECTION ACTIVITY	CONDITION CODE
			REASON FOR REPARABLE CONDITION	
	SERIAL NO./LOT NO.	UNIT OF ISSUE	REMOVED FROM	REPAIR CYCLE DATA Base Acct. No. Removed Received in Base Supply Date To TMD Received At SRA Ordered By Maint. Received in Maint. Shop Made Serviceable
	CONTRACT OR PURCHASE ORDER NO.	QUANTITY	INSPECTOR'S NAME OR STAMP AND DATE	
REMARKS				

REPLACES AF FORM 30D WHICH MAY BE USED IN THE USAF

DD FORM 1577-2, 1 OCT 66

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WARNING: Unauthorized persons removing, defacing, or destroying this tag may be subject to a fine of not more than \$1,000 or imprisonment for not more than one year or both. (18 USC 1361)	FSN, PART NO. AND ITEM DESCRIPTION		UNSERVICEABLE (CONDEMNED) TAG - MATERIEL	
			INSPECTION ACTIVITY	CONDITION CODE
			REASON OR AUTHORITY	
	SERIAL NUMBER/LOT NUMBER		INSPECTOR'S NAME OR STAMP AND DATE	
	UNIT OF ISSUE	QUANTITY		
REMARKS				

REPLACES AF FORM 30E, WHICH MAY BE USED IN THE USAF.

DD FORM 1577, 1 OCT 66

R
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D

NCS8-749

Figure 3-3. DD Forms 1574, 1577, 1577-2.

The type report includes High Accident Potential (HAP) reports.

Nuclear safety deficiency. This is any materiel, engineering, or procedural deficiency that could cause (or contribute to) a nuclear accident, incident, or deficiency. Such a deficiency can be reportable both as Category I and as a DULL SWORD (flag word for nuclear safety deficiency). If this happens, the submitting organization may submit a combination Category I and DULL SWORD. AFR 127-4, *Investigating and Reporting US Air Force Mishaps*, spells this out. You must submit a combined report within 48 hours.

Critical safety deficiency. This type of deficiency exists when there is a malfunction of a part, component, or installation, causing a hazard that requires quick corrective action.

Explosive safety deficiency. This fourth deficiency presents a known or suspected danger to personnel and equipment. It can be caused by a malfunction, unintentional acts, and the detonation of ammunition or an explosive during use, handling, or storage.

Repeat Category I report. This is a report of a deficiency that is determined to be identical to one previously submitted as Category I within the past 12 months while the first deficiency is still under investigation.

Category II report. This category identifies two main deficiencies. The first deficiency covers nonwork unit coded items, and the second covers quality deficiencies in materiel. Category II conditions cover degrees of risk thought to be tolerable within broad time limits.

Nonwork unit coded items. These are items with design and maintenance materiel deficiencies. These deficiencies do not have a safety impact, but if they are not corrected, prolonged use of the items could:

- a. Constitute a hazard.
- b. Have a negative effect on operational efficiency.
- c. Reduce tactical or tactical support ability.
- d. Reduce operational life or general service utilization of equipment.
- e. Create economic problems (manpower and money).

Quality deficiencies in materiel. The second type of deficiency is charged to applicable publications, drawings, standards, technical orders, and errors in workmanship. Another possible deficiency is failure to provide or account for all specific parts, or the presence of other conditions that can be traced to nonconformance during manufacture, repair, modification, or maintenance.

Methods of Reporting. All Category I and Category II MDRs will be prepared on a DD Form 173, Joint Messageform using the format prescribed in TO 00-35D-54, figure 3-2. The MDR originator should use Standard Form (SF) 368 as a worksheet to draft the MDR.

Category I reports. Category I reports must be submitted by electrical transmission within 72 hours after discovery. Use Category I reports to report the conditions we have already identified. These reports instigate investigations that must receive the highest priority possible at the action and support points. In the case of grounding action or the removal from service of like items, continuous (round-the-clock) action must take place until the problem is solved.

Repeat Category I reports. If the same deficiency occurs during the time a Category I report is being investigated, another Category I report must be submitted in support of the first one.

Category II reports. Submit Category II reports by message within 15 calendar days after discovery. Make these reports on the deficiencies previously described.

Conditions Not to be Reported. A table in TO 00-35D-54 lists the deficiencies, conditions, and equipment that should *not* be reported under the materiel deficiency reporting system. It includes deficiencies in TOs. If you recall the information you studied in Chapter 2, TO deficiencies are reported under the TO improvement program. Therefore, before submitting a report under the materiel deficiency reporting system, check TO 00-35D-54 to make sure that the deficiency should be reported under this system. The quality control section of the maintenance management system coordinates the materiel deficiency program.

Exercises (017):

1. What type of materiel deficiency report should be used to report a nuclear safety hazard?
2. When you have a DULL SWORD deficiency, how should you usually report it?
3. What type of materiel deficiency report is turned in to report a materiel deficiency caused by an error in workmanship?
4. Why are TO deficiencies not reported under the materiel deficiency reporting system?
5. Name the maintenance management activity that controls and coordinates the materiel deficiency reporting system.

3-5. Production Control

Production controls include mechanical and graphical standards, time budgeting, and work scheduling. Mechanical standards are largely determined by your AFSC, the STS, and the types of tools and test equipment required on the job. Graphical standards can be prepared at the shop or at higher levels with specifically designed forms and graphs. A chart can show you at a glance what jobs your people are working on, how the jobs are progressing, the radar and systems involved, etc.

018. Identify the main principles in determining the actions necessary to ensure continuous high-quality production.

Performance Standards. One of the biggest problems we face is the determination of performance standards. To ensure our personnel meet their objectives, we must set standards for them. In some cases the standards are handed to us from higher authority. In others, we are faced with devising standards of our own to fit the job. Although short in rank, you may be a supervisor early in your career. For that reason, the following paragraphs may refer to you as the supervisor.

A supervisor must know the capabilities of his or her personnel. Just as important, each person must know what is expected of him or her. Wise use of performance standards will greatly reduce confusion and will improve work quality in your section. During your daily activities you should look at your area and make sure that your people are meeting the standards.

In the event an area is falling below standard, you should set up a program to get it back to standard quickly. You noticed we used the word "quickly." This is important to the supervisor. If you let something slip for a while because you have other things to worry about, the substandard condition could become accepted as the standard. All Air Force supervisors have the responsibility of supporting established performance standards.

Maintenance and Inspection Reports and Charts. Maintenance and inspection reports are very important in the job of a supervisor. The supervisor has many daily and monthly maintenance reports that he or she can use to get ideas as to where the workers are being employed most of their time. These reports are prepared from information that is supplied on maintenance forms. In addition, the squadron analysis section keeps a complete record of all writeups from your section.

Careful analysis of these reports can help pinpoint problem areas in your equipment. An example would be: While reviewing your monthly maintenance report, you noticed that a large percentage of the maintenance hours were spent on one item. Further investigation showed that the cause of the failure was always the same. With this information you should make a thorough check of the equipment involved and the procedures used to maintain it. You may find it necessary to increase training in order to ensure proper maintenance, or it may be a highly technical problem requiring assistance from other sources. Proper use of maintenance reports can identify trends that could cause serious problems in the future if not corrected as soon as possible.

Charts and graphs are often useful to the supervisor as he or she compares several items against each other such as time versus failures. A word of caution here is to limit the use of the charts or graphs. They must not be so complicated that they cannot be read. A chart, such as a training chart, can have many training operations indicated and still be readable. However, if the supervisor starts adding leave schedules, annual shots, and other items that he or she wants to know about his or her people, then the training cannot be determined quickly. Graphs are limited

more than charts. If we are able to read and understand a graph, it should be limited to not more than five items.

Organizational and Functional Charts. The time to start establishing good employee relations is during your newcomers' briefing. You can use the organizational chart during this briefing to show the individuals how they fit into the support of the unit's mission.

Normally, an organizational chart shows one level of supervision above and two levels below the charted position. One above your position should be your supervisor. The one below you would be your assistant and below that perhaps would be the team chiefs. The above example is purely hypothetical.

A more detailed briefing in each position can be given with the use of a functional chart. The functional chart will be much like the organizational chart, except the duties and responsibilities of each position will be listed on the functional chart. It may also list job descriptions and Air Force publications required to perform the assigned task.

Exercises (018):

1. Why should a supervisor correct substandard performance quickly?
2. When should the supervisor check to make sure the people are meeting the standards?
3. How may the supervisor identify problem areas developing in the equipment?
4. What precaution must be taken when using charts and graphs?

3-6. Property Control

To accomplish the mission of the Air Force we have many thousands of items. Among these are spare parts, special tools, maintenance equipment, pencils, paper clips, and other items. The cost runs into billions of dollars. This property is stored, issued, reissued, and sometimes lost or destroyed. Here we will discuss some of the controls and responsibilities for Air Force property.

019. Identify the main principles governing supply authorization and management of expendable supplies.

Supply Authorization. The equipment authorized for your unit is based on two general factors—the unit mission and the number of people. These factors are interrelated; for

example, if performance of the mission requires certain vehicles, then operator personnel must be authorized and quantities of other items of equipment based on the number of people who are affected. The equipment authorized to your unit is based on USAF allowance documents. These documents reflect the average minimum quantities of equipment items needed to accomplish the mission. However, the allowance documents do not necessarily reflect the exact quantities your unit will be authorized. Each quantity is determined by major commands and base equipment management offices. They're influenced by such factors as the number and types of equipment to be maintained, the type of maintenance performed, the number of personnel, and the climatic conditions.

Tables of allowance (TAs). The USAF tables of allowance are the authorization sources quoted in requests for issue. They provide a list of equipment in the quantity normally required by the mission of an Air Force activity.

TAs can be used to authorize additional equipment. For example, the equipment you now have could be replaced with a new and different type of equipment that requires additional test equipment. In this case, you would quote the applicable TA as authorization for the additional test equipment.

Expendable supplies. These are items which are either consumed or lose their original identity by incorporation into another assembly. Office supplies such as paper and pencils are examples of items consumed in use. Bench stock items, such as nuts, bulk hose, seals, and repair kits are items which are incorporated into another assembly.

Bench stock is a working stock of nonrecoverable items.

It is required to provided uninterrupted operation and expedite maintenance. One shop bench stock may be authorized for each maintenance shop area, or the bench stock may be combined when two or more shops occupy the same area.

Transactions with A&A and MSS. A&A, or Allowance and Authorization, is responsible for control of the base equipment management system. So far as your unit is concerned, A&A is the source of supply. Also, it receives all equipment requests for nonexpendable items listed on the TA for your organization. Examples of these items are tools, machines, and clothing.

MSS, or the material support section, controls and issues repair parts and maintenance items. These items fall into two categories (1) bench stock, which consists of miscellaneous items of expendable hardware, and (2) repair cycle items. MSS also issues local purchase items, such as pencils and paper clips.

For requesting supplies you will most likely find local and Air Force forms used. For supplies available through Supply, the AF Form 2005 shown in figure 3-5 is usually used. For supplies that must be bought "local purchase," the DD Form 1348-6 shown in figure 3-4 will most likely be used. The AF Form 2005 can also be used for turning supplies back in to the supply system. These forms may later be replaced but for the time being, let's review some of the information that will be required by them. Keep in mind that these forms have a dual purpose; they are used for either issue or turn-in of equipment or supplies. Turn-in is appropriate for excess or unserviceable property. Your unit supply custodian will indicate which action is required. Now let's see what type of information goes on the form.

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DD FORM 1 APR 77 1348-6

NON-NSM REQUISITION (MANUAL)

NGE13-168

Figure 3-4. DD Form 1348-6.

ISSUE/TURN-IN REQUEST

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AF FORM 2005 JUN 83 PREVIOUS EDITION WILL BE USED. NGE13-169

Figure 3-5. AF Form 2005.

- Date of request and unit designation.
- A unit supply request number (for identification or followup action).
- The name and telephone number of the unit supply custodian.
- Equipment stock number or part number and name or description of the item.
- Justification of request. This will include citing the allowance documents applicable and a brief statement of circumstances.
- The quantity required.
- A certificate by the commander or his or her representative that the requirement is valid.

Because most of our assignments are manned with the minimum of additional AFSCs, such as Supply, you may become an equipment or supply account custodian. Once you've been chosen for this kind of additional duty, you'll have to attend some schools on the subject. The schools are short, usually a few hours to a day long, and they'll explain what goes on with an account.

Exercises (019):

1. What factor is involved in determining what equipment may be authorized by a TA?
2. The USAF allowance documents reflect the average minimum equipment needed to accomplish the mission. Who determines what quantities are issued?

3. Describe expendable supplies.

4. Who handles the equipment request for nonexpendable items listed in the TA for your organization?

020. Specify forms used to release a custodian from property responsibilities for lost, stolen, or damaged equipment when there is negligence and carelessness indicated.

Lost, Damaged, or Destroyed Property. The monetary loss to the Air Force must be accounted for in some manner when property is lost, damaged, or destroyed. The person with responsibility for the property may have to reimburse the Air Force. If not, the Air Force will have to sustain the loss.

Two methods of being relieved of property responsibility involve the use of a "cash collecting voucher" and a "statement of charges". These two forms are used to reimburse the Air Force when pecuniary or monetary liability is admitted. The damage to, or the list price of, the article cannot exceed \$500 to use these methods. Keep in mind that even though the individual has paid for the loss, the property does not become the property of the individual.

The least troublesome way to settle a monetary obligation is to pay in some form of cash. The Cash Collection Voucher, DD Form 1131, is generally prepared by the responsible officer to cover the cash collections for a particular period of time. Listed on the cash collection voucher are the names of airmen, the articles lost or damaged, and the amounts involved. The voucher shows the complete Air Force description of the items involved

and the purpose for which collection was made. Negligence and carelessness may be indicated as the causes of damage to the property. The statement "Used in Lieu of Report of Survey" is an indication that pecuniary liability has been admitted. Before the money is turned in to the finance office, the cash collection voucher must be approved by the individual's commander. Cash collection vouchers are sometimes prepared by supply personnel. What do we use to make the payment with if we do not have the money with which to pay?

Airmen and civilian employees use the DD Form 362, Statement of Charges for Government Property Lost, Damaged or Destroyed, when pecuniary liability is admitted but a payroll deduction is desired. This is in lieu of cash payment. Like the cash collection voucher, the damaged item's price cannot exceed \$500. The individual is charged the cost of the articles or allowed up to 25 percent depreciation. This is why the actual cost may be less than the prices listed in the top section of the form. When the individual signs a statement of charges, he or she has made an acknowledgement, an authorization, a waiver of right, an affirmation, and an agreement. The commander must certify this form before it is submitted for a payroll deduction.

If an officer admits liability and cannot pay with cash, he or she uses DD Form 114, Military Pay Order. This authorizes a deduction from his or her pay for the amount involved.

Exercises (020):

1. Identify the two forms used by the Air Force to be reimbursed for lost, damaged, or stolen property valued at or below \$500 listed price.
2. Explain why there might be a price of \$200 listed at the top of a statement of charges form and a price of \$185 listed at the bottom.
3. What are some of the things an individual agrees to when he or she signs a statement of charges form?

021. State the purpose of the report of survey.

Report of Survey. A report of survey is an instrument for explaining and recording the circumstances which involve the loss, damage, or destruction of Air Force property. When used, it supports the dropping of property from the records. It also serves to resolve the questions of responsibility for loss and it fixes liability. In summary, when one individual will not admit liability or when the amount to be charged is over \$500, a report of survey must be prepared.

Preparing the report of survey form is the first step in the report of survey process. The individual who has custodial responsibility for the property starts the process. A provision has been made for others to perform this duty for him or her. This is only when it is impractical for the custodian to fill it out. Since the report of survey is a means for explaining the loss, damage, or destruction of Government property, the responsible individuals should include all pertinent facts and circumstances surrounding the loss. It's important that reports of survey be initiated and processed within 30 days of the date the loss was discovered. The investigation must be made while the persons involved, including witnesses, are available and facts are still fresh. After the report is complete, it goes to the base appointing authority for review and appropriate action.

If the report of survey is approved, the individual will be relieved of the pecuniary responsibility of the individual equipment. He or she need not reimburse the Air Force for the cost of the item. However, if the authorities decide the individual was negligent, he or she will have to reimburse the Air Force.

Exercises (021):

1. What is the purpose of the report of survey?
2. Who prepares a report of survey?
3. What is the maximum delay allowed after a loss is discovered before a report of survey must be initiated?

022. Identify methods used to justify personnel and equipment.

Justification for Equipment and Manpower. Justification for personnel and equipment was briefly discussed earlier in this chapter. You already know that to accomplish the mission you must have the necessary equipment and manpower. In today's Air Force, radar systems are being modified every day. Some systems may be removed, improved, or replaced with a completely new system. This may affect your manning and required maintenance equipment. Excessive overtime required to support the mission may indicate undermanning or lack of training. There are many areas that you must look at very closely as you justify personnel. For a starting point, look at the unit's mission. Are you doing tasks normally assigned to other sections? Have your operational hours increased because of additional wing flying hours? Also check the unit manning document (UMD) to see how many people are authorized. The UMD may authorize more people than are assigned at the present time. It should be brought to the attention of the commander that the mission cannot be supported properly.

Before additional equipment and personnel can be authorized, you must have all the facts. The commander normally keeps close watch over his or her manning and equipment authorization. It is possible, however, that you may supply one small fact that may be justification for emergency manning or reassignment of work to other sections. The same is true of equipment. Replacement of faulty equipment or that which is in limited supply and hard to repair may be justified. The commander may want to review the facts with you to ensure that he or she has all the necessary information clearly in mind before going to higher levels of command for help.

Exercises (022):

1. List those conditions that may affect manning and equipment authorization.

2. Why may the commander wish to review your facts?

Maintenance Principles

IN TODAY'S WORLD of electronics, things are changing so rapidly that the equipment and personnel can hardly keep up with the requirements. Our career field is using equipment that spans over four decades of technology. You are going to be required to operate and maintain this same equipment. The equipment can be so old that it uses mechanical relays and huge keyer-tubes, or so new that microelectronics and computers do all the work. Our problem is that we have to be able to function in either world or anywhere in between. The one bright thing about all this is the fact that basic maintenance principles work in all the aforementioned worlds. In this chapter, we'll discuss the classifications of maintenance and how each applies to you.

4-1. Classification of Maintenance

Because our equipment and jobs are so diversified, we must know the different classifications of maintenance, what is required or performed in each class, and what the limits on each are. AFR 66-45, *Joint Regulation Governing the Use and Application of Uniform Source, Maintenance, and Recoverability (SMR) Codes*, identifies the different levels of maintenance.

023. Identify the classification of maintenance required for specific jobs.

Organizational Maintenance. Organizational maintenance is that maintenance which is the responsibility of and performed by a using organization on its assigned equipment. Examples include inspections, servicing, lubricating, and adjusting and replacing parts, assemblies, and subassemblies.

Intermediate Maintenance. Intermediate maintenance is that maintenance which is the responsibility of and performed by designated maintenance activities for direct support of using organizations. Its phases normally consist of calibration, repair, or replacement of damaged or unserviceable parts, components, or assemblies; the emergency manufacturing of unavailable parts; and providing technical assistance to using organizations.

Depot Maintenance. Depot maintenance is that maintenance performed on items requiring overhaul or a complete rebuilding of parts, assemblies, subassemblies, and end items, including the manufacturing of parts, modifications, testing, and reclamation as required. Depot maintenance serves to support lower categories by providing technical assistance and performing that

maintenance beyond the lower categories capabilities or responsibility.

As you read over each of these levels of maintenance, you can see how they are similar, yet different. For our part, we'll be working at the organizational level under normal situations. On some occasions, you may have to do some jobs related to the intermediate level. There will also be rare occasions where a depot team will come to one of our units to do depot level work on our equipment and we may find ourselves working with them. Under normal situations though, we stay at the organizational level performing those assigned tasks. If we have to go to any higher level, we'll seek and receive help from our supporting agency or the depot. In the later sections of this chapter, we'll discuss some of the work we do at the organizational level.

Exercises (023):

1. What level or classification of maintenance is responsible for providing direct support to the using organizations?
2. What maintenance classification is responsible for completing overhauls of equipment?
3. What maintenance classification is responsible for performing lubricating routines?

4-2. Preventive Maintenance

The best maintenance is preventive in nature. Potential problems can be detected and corrected before they have a chance to develop. Preventive maintenance consist of measures taken to achieve maximum efficiency in performance, to ensure continuity of service, to reduce major breakdowns, to lengthen the useful life of the equipment or system, and above all else, to ensure that the mission gets done.

024. Identify factors that must be considered when scheduling and planning preventive maintenance actions.

Scheduling and Planning. In a typical preventive maintenance program, there are daily, weekly, and other periodic checks and observations that must be made to determine actual equipment performance and to compare that performance with optimum performance standards. Some checks can be made while the equipment is operating, others have to be made when the equipment is shut off. As a radar repair specialist, you will be concerned either directly or indirectly with scheduling, planning, performing, and evaluating preventive maintenance (PM).

The first thing that must be considered when PMs are being scheduled is the unit's mission. PM routines that take longer amounts of time must be scheduled during downtime hours. Shorter PM routines can be scheduled during low activity times. In either case, your maintenance control section will have to take all these things into consideration prior to delegating the work.

The frequency of preventive maintenance inspections (PMIs) is predetermined by technical order workcards. This may lead you to believe there is no planning necessary from your section, but take a closer look.

You have been in the field long enough to know that the time, manpower, and equipment needed for PMs vary widely. Some jobs entail moving heavy equipment and may require additional help. The degree of difficulty varies from job to job, and the time allowed for completing the tasks is limited. So you can see that the radar supervisor must work closely with Maintenance Control in planning the maintenance schedule.

With the necessary information, Maintenance Control issues the preventive maintenance schedule covering all the routines that must be performed on the equipment. It should notify you of scheduled maintenance periods well in advance of the actual working period. This notice allows the schedules to be modified and the necessary people and equipment to be readied.

The result of all this scheduling and planning is a maintenance program that performs its preventive maintenance while not interfering with the operational mission.

Exercises (024):

1. What is the first thing to consider when scheduling PMs?
2. When should longer PMs be scheduled?

025. Identify the type of preventive maintenance action for a given situation.

Preventive maintenance actions are divided into separate actions such as inspections, cleaning, and performance checks. In this section, we'll discuss each need and give examples.

Inspections. Inspections often don't appear to be real actions but by performing them properly, other maintenance actions can be prevented. Your TO workcards or actual TOs will often tell you to do visual checks. Most often these entail such things as checking lights (on or off), fluid levels, worn or damaged cables, oil leaks, smoked or burned appearing components, etc. While you're performing the visual inspections, there are inspections that "the book" doesn't call for, yet should be done. Once you get used to a piece of equipment, you'll become very familiar with its smell. Electrical components give off odd odors when they begin to burn out or open. Oil leaks can often be smelled before they're seen. You'll also find that your other senses will detect odd sounds such as a motor's bearings deteriorating or you'll sense that there's too much heat coming off a transformer. If in doubt about such items found during an inspection, check the cause out further or ask assistance from a more experienced coworker. It's always best to get a second opinion. That potential problem, found by inspection, can be corrected and the mission can be performed without interruption.

Cleaning. Here's a job that everyone has to perform at some point in a career. It's also a job you'll be assigned to perform often, especially early in your training. Don't take it as a derogatory job; it's not! It is just one of many jobs that have to be performed to keep the whole system working properly. Dirty equipment can result in serious equipment damage and serious damage results in big monies being spent to replace that damaged equipment. If assigned to clean something, do it well.

Cleaning is one of the PMs designed to prevent future equipment damage. In most cases, the cleaning actions will be in the form of cleaning air filters, removing dust buildup, or wiping up fluid leaks. Some of our newer equipment is especially sensitive to dirty environments. Older equipment seems to run on and on through almost any kind of situation, but newer equipment is more delicate. One thing common to all electrical equipment is that it all has to be cooled by air flowing through the equipment. That air is filtered and filters get dirty sooner or later and that means they have to be cleaned. The TOs for your equipment will show you where all the filters are and often explain how they should be cleaned. If these filters become dirty and eventually clogged, there is a very good possibility of damaging the equipment, possibly even burning it up.

Another cleaning area is that of dust buildup. Electronic components are designed to be connected to form a whole circuit or unit. Often, these components have exposed wires positioned close to each other. As the components operate, current flow occurs through these wires and creates an electronic field around the wires. The equipment designers lay the circuits and wiring out so that one circuit normally won't interfere with another, but along comes the factor of dust buildup. Dust buildup has been known to

cause arcing between wires and/or components. Excessive arcing can result in damage to circuit components and wiring. So, as you can see, your cleaning job prevents such buildups and thus prevents possible equipment damage. Whenever assigned to do cleaning PMs, remember to be gentle with the circuitry. In most cases you'll be using some kind of cleaning brush and possibly a vacuum cleaner. As you work with a unit, be careful not to knock anything loose or to break anything.

Occasionally, while cleaning, you'll have to use some type of cleaning agent on the equipment. There are some simple rules to follow when these actions are required. First and foremost, always use the cleaning agent in a well ventilated area. Second, use only the cleaning agent called for by the TO or the supervisor and don't use excessive amounts. Excessive amounts of agent could cause damage to the components or circuitry.

Performance checks. Performance checks are separate functional checks of the equipment to see if it is doing what it is supposed to do. The total operation of a particular system is made up of numerous functions that are often overlooked or lost in the overall picture. A given function may not be exactly correct and may go unidentified by the operator. That malfunction may result in a missed mission or an incorrect mission evaluation. Performance checks are conducted during the PM time to evaluate the equipment and to identify problems before they occur. Because performance checks evaluate the equipment, the worker performing the task should have two things established prior to starting the check. First, the worker should have a good general theory of what a particular performance check is checking. All the manual is going to do is to tell you to turn knob "X" to a given position and to observe such and such response. If the response is within the established tolerances, the check is good. The theory comes into play when the check results in a response that isn't within the established guidelines. You are going to need some theory knowledge as to why this response was off. Once the preventive maintenance action identifies a problem, the corrective maintenance actions must start and the theory can help establish a starting point in the corrective action.

The second thing, you, the worker must establish is the knowledge of the performance check performance. You must be able to read the manual and to follow the steps of the routine. The TO manual has been laid out in a sequence to get you from point A to point Z and if not followed, erroneous results could be observed which, in turn, could cause erroneous troubleshooting or alignments. Performance checks often require the use of additional test equipment or of built-in test equipment. In any case, you're going to have to know how to follow the TO, use the test equipment, and to perform the steps of the routine. You'll also have to be able to make decisions as to whether the equipment is meeting the established levels or not and if not, what to do about it.

All of these things connected with performance checks come through your unit's OJT program. Nobody expects you to come in and to know it all. You are going to be trained in circuit theory, the use of test equipment, and the performance of the performance checks. It all works like building a house. A foundation has to be laid and then small

parts will continue to be added until everything is completed.

Preventive maintenance, as you've just seen, covers quite a bit of work and we haven't gotten into anything "heavyweight" yet. Many hours of your time will be spent doing inspections, cleaning, and performance checks. To the overall health of your assigned equipment, the unit, and the mission, preventive maintenance is very important. The bottom line is just what the name implies, preventive maintenance.

Exercises (025):

1. What type preventive maintenance (PM) action results in your checking for worn cables?
2. What type PM action requires you to check a power supply using a voltmeter?
3. The computer cabinet of your system continues to be too hot. What type PM action is designed to prevent this?

026. State the effects and treatment of climatic deterioration.

Climatic Deterioration Prevention and Treatment.

The purpose of climatic deterioration prevention is to prevent arcing, frequency drift, short circuits, and the general deterioration caused by excessive humidity, condensation, and the resultant growth of fungi. These are constant threats to electronic equipment operation.

Some effects of climatic deterioration are:

- a. Moisture causes swelling that may move the supports out of alignment, resulting in binding of parts.
- b. Moisture provides electrical leakage paths, causing flashover and crosstalk.
- c. Fungus growth reduces resistance between parts to such an extent that the parts are useless.
- d. Rotting caused by moisture destroys protective material.
- e. High temperature and moisture vapor cause rapid corrosion.
- f. Different metals with different potentials cause electrolysis when moisture is present.

There is a preventive treatment which, if properly applied to electronic equipment, provides a reasonable degree of protection. It guards against fungus growth, moisture, corrosion, salt spray, insects, cold, desert heat, etc. The treatment consists of applying an approved lacquer or varnish coating with a spray gun or brush. The coating may be called moisture-fungus proofing (MFP) and should be reapplied whenever your work causes the old coating to be removed.

Exercises (026):

1. What effect does heat and moisture vapor have on corrosion?
2. What should be done to a piece of equipment if its original coating has been removed?

027. Identify problem areas that can be discovered by closely monitoring and evaluating the preventive maintenance program.

Evaluation. Even though everyone does an excellent job and the work is well defined, preventive maintenance programs still must be monitored and evaluated. The monitoring and evaluating will give a complete record of maintenance progression and quality.

The recorded information will be very useful during future maintenance periods. Suppose that breakdowns are often isolated to the same item or unit. This problem requires a careful evaluation of the routines involved in the breakdowns. It may be found that the routines are not being performed thoroughly or lack certain steps needed to prevent a recurrence of the breakdown. The monitor may have to recommend changes to the routine, increase the intensity of training in the area, or monitor more closely to ensure that the routine is properly performed. Evaluation team reports and reports from inspection teams will also improve the effectiveness of the maintenance program.

A comparison of data taken on a particular piece of equipment at different times can reveal slow progressive drifts that are too small to be significant in any one test. While the week-to-week changes are slight, they should be followed carefully so that replacements or repairs can be made before the margin of performance limits is reached. Regard any marked variations as abnormal and investigate them immediately.

Another advantage of keeping systematic records of performance and servicing data is that maintenance personnel develop a more rapid familiarization with the equipment involved. The accumulated experience contained in the records simplifies the task of analyzing equipment malfunctions and serves as a guide to swift and accurate troubleshooting.

Exercises (027):

1. Place a checkmark in the space provided for each problem area you would expect to identify by monitoring the PM program.
 - ___ 1. Damaged RF plumbing.
 - ___ 2. Routines not being performed thoroughly.
 - ___ 3. Routines needing changes.
 - ___ 4. Repairmen needing training.
 - ___ 5. Discolored, burned, or cracked wiring.

2. How can a slow, progressive deterioration of equipment be detected?

4-3. Corrective Maintenance

Corrective maintenance is defined as "returning equipment to operational status or serviceability." As covered earlier in this chapter, a lot of our time is spent trying to prevent maintenance problems from ever occurring. We covered cleaning, inspections, and performance checks and if you remember, we said that if a problem was found during these PMs, the worker would have to change "hats" and start the corrective action. Well, here we are and we're going to discuss the actions performed in corrective maintenance.

028. Identify the type of corrective maintenance safety required when working with solid-state devices.

Safety. Before we get into the types of corrective maintenance, let's review a few old safety ideas and introduce a new one. Chapter 1 of this volume covered safety, but you need to remember to always have a safety observer with you, stop and think about what you're going to do, and then follow all safety directives. The new safety related area comes in the form of safety for the equipment. This area has been added because of the new solid-state circuitry now in the career field. This area deals with electrostatic discharge. New semiconductors, custom integrated circuits (ICs), converters, etc., are so sensitive to a static discharge, your body can produce an electrical jolt that can simply blow up some of these circuits just by you handling them! If your corrective maintenance action requires you to handle some of these type devices, there are ways to minimize the chances of destroying them. They are:

- Know that there is a potential problem. The TO will have certain areas identified as being susceptible to electrostatic discharge (ESD).
- Know the guidelines for handling these type devices.
- Use the guidelines. Follow them to the letter.

Figure 4-1 shows some of the ESD procedures. With the increase of new, state-of-the-art equipment in this career field, the ESD problem is something we're going to have to learn to live with as we conduct our corrective maintenance actions.

Exercises (028):

1. What reference material should identify whether an IC chip is ESD sensitive?

There are troubleshooting analysis charts in your technical manuals. These cover the malfunctions that occur over and over again in specific equipment. In addition to these common troubles, you will find many problems peculiar to the specific set (or system) on which you are working. Unusual problems force you to use your information resources and your experience to solve them. Thoroughly analyze every malfunction as a part of the troubleshooting procedure. This is a challenge that you must be prepared to accept; only on your own initiative can you succeed. In addition to the resources that we have already noted, you must know how to use the test equipment.

If you do not recognize symptoms of trouble through routine checks or reports, you will waste many man-hours. Without careful examination, you can overlook early signs of trouble. Many troubles can be spotted through indicator presentations, equipment meter readings, and performance reports. Some troubles, such as low receiver sensitivity, however, are not readily apparent and must be detected through periodic performance checks. To minimize downtime, you must develop a system of troubleshooting, including an examination of all available equipment records, an evaluation of the operator's comments, and the use of operational checks when possible.

Locating the trouble is usually the most difficult step in corrective maintenance and is, therefore, the one to which we give the most emphasis. A technician's troubleshooting technique is based on his or her knowledge of the operational standards and of the block diagram of the equipment. As part of the technique, you must be able to read and understand technical literature, such as cabling charts, schematics, and voltage and resistance charts.

The important things to remember in troubleshooting are:

- a. Use your block diagrams.
- b. Narrow the trouble down as far as possible with indications from the equipment itself.
- c. Look for the most common troubles (fuses, mis-set controls) first.
- d. In most cases, check voltages or waveshapes before measuring resistance.
- e. Analyze the symptoms carefully before removing any components. A little effort in this direction can save a lot of time and labor.
- f. Check the records. Do not overlook the importance of your fellow worker's previous experience. He or she may have encountered the same trouble that you must deal with.

Repair. Repair actions are often interpreted to include any and all actions needed to make the system operational. This interpretation is extremely broad and doesn't fit into our flow of thought at this point. For our uses, the term "repair" needs to mean "remove and replace." When we troubleshoot, we attempt to eliminate options until we get down to the one most likely to be causing the problem. If the identified item can be removed and replaced with a like item from Supply, the "repair" action has been done as far as the overall system is concerned. Once the new item has been installed, the system alignment checked, and a performance check completed, the overall system can again be called operational. In this case, the repair action on the

system was to remove and replace a bad unit. If the troubleshooting found that the system was out of adjustment or alignment there would be no "repair" or "remove and replace" action. In this case, you'd go from troubleshooting to alignment to performance check and then back to being operational.

Since each repair action is an individual problem and differs from previous repairs in some respect, it is almost impossible to set up a routine or production line technique for dealing with repairs and to have it followed. In the situation mentioned in the previous paragraph, the object was to bring the overall system back to operational status. In that situation, we removed and replaced a whole unit because in most cases like that, we're fighting time. Now, once the mission is over or some downtime exists, further "repair" action will be needed on the bad unit. The whole process starts over with troubleshooting, removal and replacement of the defective part (tube, resistor, broken wire, etc.), reinstalling the unit into the system for alignment and performance checks, and then returning one of the two units to Supply. As you can see, two different situations causes two different repair actions.

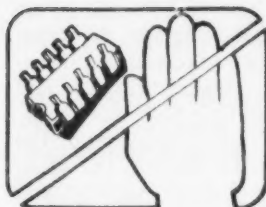
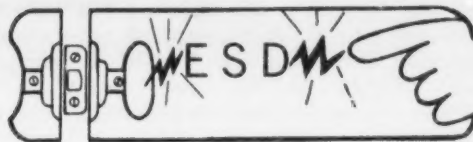
The main thing to keep in mind is to troubleshoot down to the most likely cause of the problem the first time. Removal and replacement actions take time, tie up Supply personnel, cause paperwork, and in some cases, cost money needlessly when non-returnable parts have to be ordered.

In today's newer equipment, the only actions required of you are to troubleshoot down to a unit, remove and replace that unit, and press on. These units are often referred to as line replaceable units (LRUs) or shop replaceable units (SRUs). LRUs are the larger units such as a transmitter unit and the SRUs would be the smaller replaceable units inside an LRU. SRUs are usually limited to printed circuit boards.

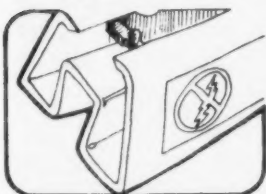
Alignments. It should be clear that it is impossible (or very impractical) to manufacture electronic components with no variation at all in their values. Of course, age, climatic conditions, vibrations, etc., can cause the values of components to change. Because of this, variable components provided in some tuned circuits require alignment. Thus, by a slight retuning or adjustment from time to time, the optimum performance specified in the maintenance manuals or by the manufacturer may be attained.

Reduced sensitivity or reduced output indicate a need for alignment, but alignment should not be undertaken until the equipment has otherwise been put into good operating condition. Every piece of equipment that is operating poorly requires maintenance, but it does not follow that every piece of equipment that needs maintenance also needs alignment. Sometimes, repairs that include the replacement of components or the redressing of wiring make later alignment necessary. Therefore, you should not attempt alignment until all problems have been corrected and all defective parts replaced. We cannot stress too strongly that *before* alignment is attempted, all available instructional or maintenance literature should be carefully consulted.

When line replaceable unit (LRU) troubleshooting, you will often be troubleshooting by pulling a card or subcomponent out and replacing it with another from a supply point. If the new circuit card you install is not



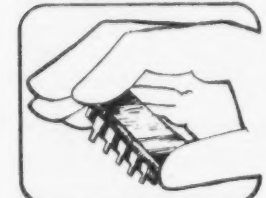
1. MINIMIZE HANDLING.



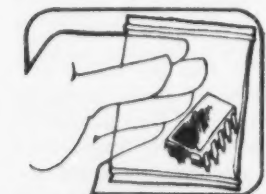
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES



4. HANDLE S.S. DEVICES BY THE BODY



5. USE ANTI-STATIC CONTAINERS FOR HANDLING AND TRANSPORT

Some semiconductors and custom ICs can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

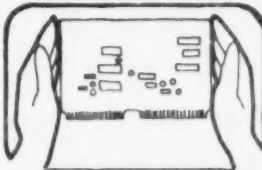
1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures and packaging and bench techniques that are recommended.



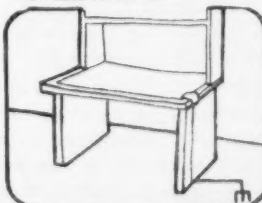
6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL, AND STYRO-FOAM IN WORK AREA



8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR USUALLY PROVIDES COMPLETE PROTECTION TO INSTALLED S.S. DEVICES



9. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION

10. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.

11. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

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2. Where should an IC chip be kept until its ready for use?

3. How should static sensitive devices be handled?

029. Identify the type of corrective maintenance required in given maintenance situations.

Corrective Maintenance Phases. As mentioned earlier, corrective maintenance needs are identified through operations, inspections, or performance checks. Once a problem has been identified, a phase of corrective maintenance must be chosen. Corrective maintenance is broken down into four basis areas. They are (1) troubleshoot, (2) repair, (3) align, and (4) performance check. There are times when all these phases are required and other times only three. There will be occasions where the repair action doesn't enter the situation. An example of this would be when a performance check reveals that a power supply is producing less than the established standard. You'd troubleshoot the power supply by seeing if it is adjustable and if it is, see if its range can be varied enough to bring the output level up to standards. If it can be, you'd align the power supply to meet the performance test standards and return it to action. If the adjustment or alignment doesn't bring the outputs to within the tolerances, your troubleshooting would lead you deeper into the unit. Eventually a tube may be found to be causing the problem. Replacing the tube may be the required repair action. Now, the power supply has to be aligned again to meet performance test standards. Once realigned and tested, the unit is again serviceable.

Troubleshooting. Troubleshooting is a process of elimination and the trick is to be able to do it fast and effectively. Troubleshooting electronic circuitry is very similar to any other kind of problem-solving. First, try to see the "big picture" of what is going on. As a troubleshooter, it's always a good idea to go back to the beginning and start all over by performing an operational check. These "ops checks" often identify the trouble as being operator error. Many an hour has been spent troubleshooting because someone missed a switch or a step. If the "ops check" doesn't show the cause of the trouble, you must next identify the conditions. Identify the inputs and the outputs and how they all relate. Next identify the trouble and how it fits into all these other bits of information. Once all this information is obtained, the half-split method of troubleshooting can begin. If all inputs are good but one of the outputs is absent, split the circuit or unit into two halves and pick a spot halfway to check circuit conditions. If everything is good at the halfway point, the trouble is from there toward the end. If the halfway point shows a problem, start troubleshooting back toward the beginning. Keep dividing the halves down until the trouble is isolated. Expect the trouble to be anything.

Figure 4-1. Electrostatic discharge procedures.

aligned, you may be putting in more problems than you are taking out. Consideration should be given to inspecting and aligning items on supply point, before you need them for troubleshooting or repair.

Performance testing. A performance test is a check to determine the condition or the operating efficiency of a piece of equipment. The first checks are performed when the equipment is initially installed. Such checks must continue to be made periodically (at the beginning of each shift, for example), at the conclusion of either preventive or corrective maintenance, and at any other time when there is reason to believe that the equipment is operating below accepted standards. At these times, you must check the equipment against the indicated performance standards in the technical manual, using the proper test equipment. These checks reveal improper or defective circuitry, and in many cases a simple adjustment can correct the malfunction that causes this condition.

Exercises (029):

1. What phase of corrective maintenance would be the last one performed prior to calling the system operational again?
2. What corrective maintenance phases would be used on a power supply that read 1/2 volt less than the standard?
3. If you had to replace a LRU on your system, what phase of corrective maintenance should follow the replacement action?

4-4. Modifications

From time to time, your equipment must be modernized so that it can meet increasing demands. In most cases, it is easier and less expensive to improve existing equipment than to design and build a new system. Safety hazards and recurring failures also demand equipment modifications. Let's look at the different classes and types of modifications and discuss where they come from and who has the responsibility for performing them.

030. Identify modifications by class and/or type.

Types. Time compliance technical orders (TCTOs) are grouped according to the importance and urgency of the work. The TCTO's instructions will indicate the degree of urgency as to when the work must be done. Four types of TCTOs are authorized.

Immediate action. Immediate action is identified by a border of red Xs and the words IMMEDIATE ACTION printed in red at the top of the first page. Immediate action technical orders are issued because of unsafe conditions that

could result in fatal or serious injury to personnel, extensive damage, or destruction of valuable property. Such conditions embody risks that are calculated to be intolerable.

Urgent action. Urgent action has a border of alternately spaced red diagonals (/) and red Xs enclosed in a red circle and the words URGENT ACTION printed in red at the top of the first page. Urgent action technical orders are of combat necessity or are issued for potentially hazardous conditions that could result in injury to personnel, damage to valuable property, or reductions in combat efficiency.

Routine actions. Routine action is printed on plain white paper without identifying marks. Technical orders of this type are issued to correct all deficiencies that would reduce the operational life and general use of equipment. They are issued in categories based upon the level of the responsible depot or organization and how long that organization has to comply.

Record type. Record type is printed on plain white paper without distinguishing red marks. This type of TCTO does not provide step-by-step instructions for doing the work because the scope or complexity of the modification is such that a contractor of specific Air Force activity, higher than organizational/field-level maintenance, must do it. However, these TOs do describe what the modification consists of, tabulate the equipment affected, provide an index of all necessary drawings and instructions, and include a list of all parts required.

Because of their critical nature, immediate and urgent action TCTOs are often transmitted by what we refer to as "interim means." This means that they are transmitted to the user by some form of a message to be followed later by the hard copy text. They are often referred to as interim TOs. Examples are radiograms, telegrams, teletypes, or airmail. Normally, an interim TO is replaced by a formal TO within 40 calendar days.

Classifications. We shall briefly explain how modifications are classified so that you will have an idea of the types that are of most concern to you.

Class I. This class covers the temporary removal of installed equipment that is not required for mission support (test scopes, additional PPIs, etc.). Such removed equipment must be kept available in serviceable condition for reinstallation so that the system or equipment can be returned to its standard configuration within 48 hours.

Class I also includes the temporary installation of equipment needed for a special mission or purpose (not to exceed 6 months) when AFSC or AFLC approved installation engineering is available without additional procurement. The temporary installations must permit the system or equipment to be returned to its original configuration within 48 hours. Class I modifications must be removed before the equipment is transferred to another command.

Class II. This class covers temporary modifications required to support research, development or operational test, and evaluation programs.

Class III. Class III covers modifications that are required to ensure production continuity and do not qualify as Class IV or Class V modifications. This class may include the incorporation of Group B equipment originally

programmed and procured but not installed during production. (We shall explain Group B equipment later.)

Class IV. This class covers three categories of modification. First are those required to ensure safety of human life, systems, or equipment and protection from operational, nuclear, and biophysical hazards. If such safety hazards could ground the systems or equipment, seriously restrict flight or ground operation, or cause unacceptable risk to personnel if not corrected, then the equipment must be modified. Modifications of this type are designated Class IVA.

Second are modifications required to correct deficiencies that would result in unacceptable mission aborts or would seriously impede the completion of the system/equipment mission. This category includes deficiencies affecting maintainability and reliability, electromagnetic compatibility, and communications security. Modifications of this type are designated Class IVB.

The third is the Class IVC modification which would result in a significant improvement in maintainability or service life, or reduce operating costs.

Class V. This class covers the modification of a system or equipment that will produce: (1) a change in operational requirements or performance that provides an added capability not inherent in the baseline configuration, (2) the capability to accomplish an assigned mission that the basic system or equipment was not originally designed to accomplish, and (3) a significant and measurable training or logistic improvement certified essential by the command or agency primarily concerned.

Group A and B kits. To further identify the term "modification" and its classifications, we include the Group A and B kits or equipment. Group A kits are items, parts, or provisions permanently or semipermanently installed in a system to support, secure, interconnect, or accommodate an item of equipment. They may include racks, cabinets, etc. Group B kits are the operating components of the equipment which, when installed in connection with the Group A parts, provide a complete, operational installation. Normally, the Group B component is readily removable.

Exercises (030):

1. Identify each of the following statements with its proper class or type of modification.
 - (1) To improve the basic system or equipment so that it will be capable of accomplishing a mission it was not originally designed to accomplish.
 - (2) Temporary modification to support research.
 - (3) Modification to improve maintainability.
 - (4) Modification to correct safety hazards that would seriously restrict ground operations.
 - (5) This TCTO has a border of red Xs.
 - (6) This TCTO is issued because of combat necessity.

031. Identify problem areas that need modification and the preparatory steps to take when installing modifications.

Modification Requirements. Now that you have learned the different types and classes of modifications, you should know why modifications are needed and who performs them.

The main source of information on equipment performance is the radar specialist in the field. Many areas in the maintenance environment become the basis for the submission of modification or change proposals. Some areas to consider are:

- a. Any item or condition that may affect the well-being or safety of personnel.
- b. Poor equipment performance, short equipment life, and early part failures.
- c. Difficulty in removing or installing certain components, units, or parts, which can be remedied by a change in procedure.
- d. Repeated equipment failure caused by the failure of one or more parts of the same type or make.

The above list is not all inclusive. It is only a small sample of areas that may need improvement.

If you decide a change is needed, discuss the change with the people in your section. They may have some ideas that could improve your recommended change. Making your idea a joint effort will motivate your coworkers to look for ways to improve equipment and procedures.

You may feel your idea is not perfect or you may think it has been submitted before, but the only way to know for sure is to submit it. All modification proposals are recognized. Some are used and some are not, but you can rest assured that your proposal will be evaluated by trained people to determine its value to the Air Force.

In cases where human lives are endangered, you must take immediate action. Modifying, changing, improvising, or substituting components can be used as a temporary measure. You may not know how to correct the situation, but you are obliged to report the condition.

In accordance with AFR 57-4, *Modification Program Approval and Management*, Class I, II, III, and IV modification proposals are submitted through command channels to the command authorized to approve the proposals. Class V modification proposals (except military assistance program modification proposals) are submitted to the headquarters of the major command in which the proposals originate.

A large percentage of the modification proposals submitted by field personnel are caused by materiel or maintenance deficiencies and usually fall into Class IV type. You will be mainly concerned with reporting materiel deficiencies in accordance with TO 00-35D-54.

Many of the modification kits that you have installed or will install are a direct outcome of the maintenance data collection system outlined in command 66-X series regulations. If the analysis of collected data indicates deficiency trends in materiel, then the facts must be investigated and appropriate corrective action taken to

remedy the situation—usually in the form of time compliance technical orders (TCTOs). Your part in this system is the accurate and timely reporting of all maintenance data.

The knowledge-level requirements for performing modifications are more or less dictated by the TCTO. The TCTO lists who will undertake the work. For most modifications, the work is done by organizational/intermediate level maintenance. Since personnel at most 303X3 sites are authorized to perform both organizational and intermediate level maintenance, installing "mod" kits will be part of your responsibilities. Of course, the degree of supervision you will need is directly proportional to the complexity of the modification. Look at some preparatory steps to ensure satisfactory installation of "mod" kits.

a. Inventory the kit.

b. Read the TCTO instructions. Make sure you understand them.

c. Check the TCTO to find out when the work must be completed.

d. Prepare for the job.

(1) Do as much precleaning and component removal as possible.

(2) Discuss the job with fellow workers to ensure complete understanding of the task.

(3) Make sure you have the tools and test equipment necessary to complete the job.

(4) Check with the supervisor to ensure that all coordination has been completed and the time needed to perform the task has been established.

Deviations from these preparatory steps may be dictated by instructions contained in the TCTO. An example of a deviation is an Immediate Action TO or a "mod" kit that must be installed by depot-level maintenance.

Don't assume that the modification is complete until you have made certain that everything is operating satisfactorily and that the modification is performing the function that it was intended to perform. Then record it and report it for maintenance management purposes.

Exercises (031):

1. List three problem areas that indicate the need for a modification.

2. List the preparatory steps to be taken when installing a modification.

Soldering and Cabling Techniques

SOLDER IS ONE of the oldest, simplest, and most useful of all the metals in use as fusible alloys. It gives real service in today's electronic industry. Without this material to bond together components, circuit boards, and miniaturized circuit chips, we would still be in the preradio age. Soldering makes the electrical and physical connections to ensure continuity for electron flow. Because of its simplicity and ease of application, soldering has come to be regarded as something to be taken for granted. This should not be the case. Engineers and technicians have found that many failures attributed to electrical components were actually the fault of poorly soldered connections. Many investigations and studies have been performed on the "soldered connection." From the results of these studies, improvements and changes in the soldering technique have taken place.

5-1. The Nature of Solder

Any discussion of soldering techniques should begin with an explanation of solder itself. This generally accepted substance is quite simple, and is relatively easy to use when proper preparation, materials, and techniques are employed.

032. Identify the different types of solders, fluxes, and their uses.

Solders. Ordinarily soft solder is a fusible alloy consisting essentially of tin and lead. When tin and lead are alloyed together, the percentage of tin to lead is expressed as a ratio, with tin as the first number. For example, 60:40 means that tin content is 60 percent and the lead content is 40 percent. There are many classes of solders available with many uses, and they can be grouped as (1) flux-core, (2) solid-wire, and (3) bar solder. In our discussion of soldering, we will be referring to the wire-type solder with rosin flux-core and a tin-lead content of 63:37 or 60:40, unless otherwise stated.

The comparison of commercial solder covers the entire range of the tin-lead ratio. Pure tin becomes a liquid at 450°F, and pure lead becomes a liquid at 621°F. When the two metals are alloyed together, new liquefaction points are created, depending upon the tin-lead ratio.

Refer to figure 5-1 and locate lines AC and BC. Note that point C represents an alloy of the lowest melting point. The

alloy at this point is 63 percent tin and 37 percent lead and is known as the *eutectic composition* with a distinct melting point of 361°F. A eutectic alloy has a melting point lower than that of any other percentage combination of the same components.

With the exception of 63:37, all solders in the tin-lead series are made up of ratios of these two metals and do not melt sharply at any one temperature. Instead, the different ratios pass through an intermediate range of plasticity before going into the liquid range. This intermediate range of plasticity also takes place in the process of cooling from the liquid to the solid state.

A working knowledge of the plastic range of solders will be helpful in selecting the type of solder needed for a specific job. For example, in plumbing, a wiping solder consisting of 50 percent is acceptable because of the long time such an alloy stays in the intermediate range of plasticity. On the other hand, in electronics, many components are heat sensitive and cannot withstand high temperatures for any length of time; so higher tin alloys with shorter ranges of plasticity are used.

Figure 5-1 shows that a tin-lead ration of 60:40 is well suited for electronic soldering work. This alloy has a low melting point and a short time in the plastic range. These characteristics reduce the time and temperature you have to put on the connection. The 60:40 solder is primarily used in conventional circuits and terminals where the melting point and flexibility of this solder can be tolerated.

The 63:37 solder is much preferred for printed-circuit boards and miniaturized parts. Its sharp and distinct melting point, along with its negligible plastic range, makes the 63:37 solder ideal for jobs where heat limitation is critical. If however, 63:37 solder is not available, you will find 60:40 solder a generally accepted substitute.

Solder Flux. Common metals exposed to the atmosphere acquire a thin nonmetallic film known as oxide. The longer the exposure, the thicker the film becomes. Oxide film forms an effective insulating barrier. As long as the nonmetallic barrier is present there can be no actual metal-to-metal contact. As a result, soldering action cannot take place.

The function of the soldering flux is to remove the oxide film from the surface of the metals and to keep it removed during the soldering process. The flux does this because its melting point is lower than the solder. As the flux melts, it first exerts a slight chemical-reducing action, loosening the trapped oxides on the metal surface. The loosened oxides,

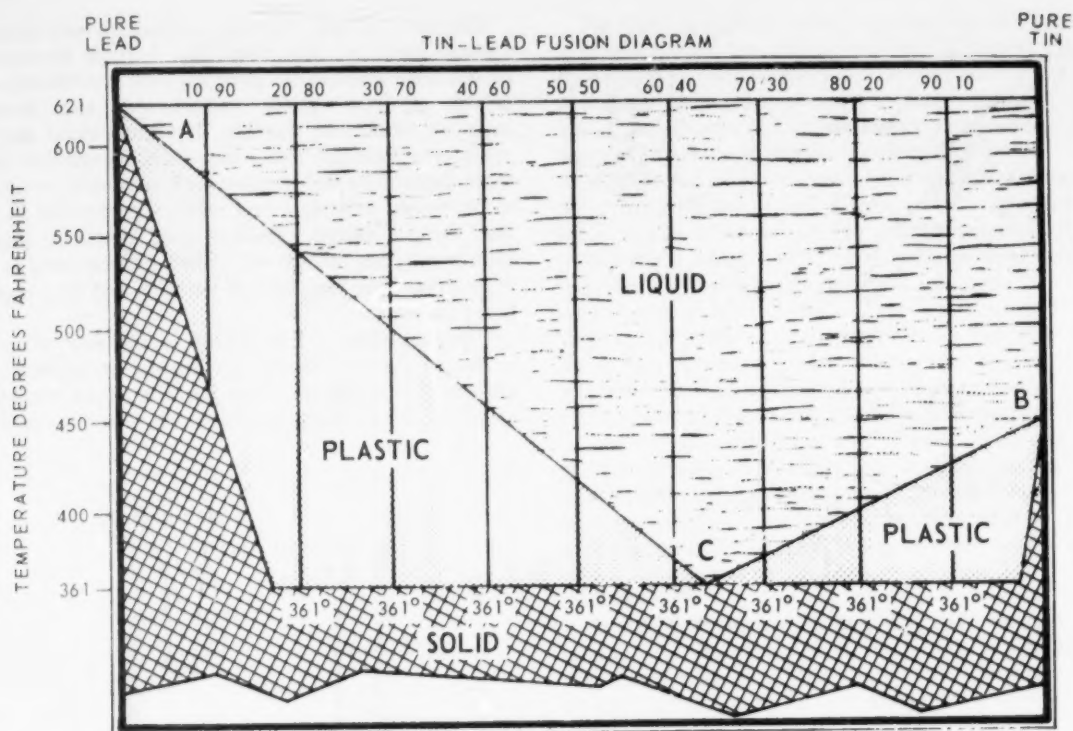


Figure 5-1.

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wet by the flux, coagulate and are suspended in the flux body. The solder then melts, floating the lighter flux and the impurities suspended in it to the outer surface and edges of the molten solder. Most of the flux is burned away during the soldering process, leaving only a small amount of tacky residue upon cooling. Because dust and dirt adhere to the rosin residue, you should clean each completed soldering joint before returning the equipment to operation.

It should be mentioned at this time that flux should not be expected to remove heavy surface oxides from metals. Heavy surface oxides, paint, shellac, sulphides, gross forms of dirt, and other inert matter must be removed by a mechanical or chemical cleaning process.

There are two classes of flux: (1) corrosive and (2) noncorrosive. Zinc chloride, hydrochloric acid, and sal ammoniac are in the corrosive class. Never use a corrosive flux in electronics repair work. If corrosive flux remains in the joint, in time it eats through the connection and creates a high-resistance circuit. All of your electronics soldering should be done with a noncorrosive, nonconducting rosin flux. Rosin flux is available in paste, liquid, and powder forms. Limit your use of liquid rosin flux to the following applications:

- a. Removing excessive solder from a joint by wicking on a stranded wire.
- b. Soldering nickel-plated wire.

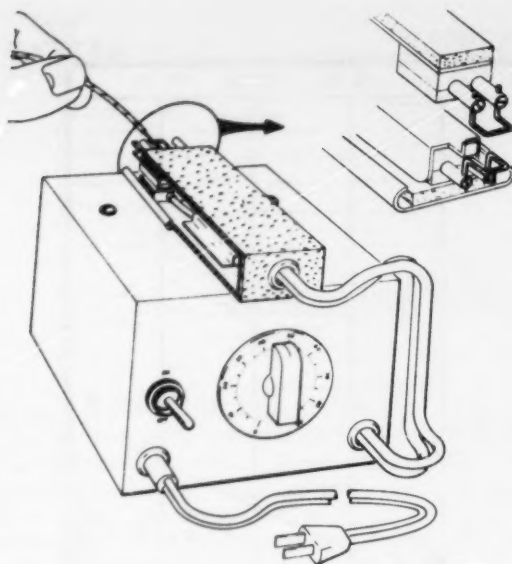
If you use liquid flux with flux-cored solder, the two must be chemically compatible.

Exercises (032):

1. What types of solder are preferred for connections in electronic circuits?
2. Name the type of solder preferred when temperature limitations are critical.
3. State the purpose of flux.
4. Why should you avoid using certain types of flux when soldering electrical connections?

5-2. Tools and Equipment

Proper soldering and desoldering of connections in electronic equipment require certain basic tools and equipment. Your use of additional specialized tools will increase the efficiency of the operation and the quality of your finished product. Our discussion will be limited to specialized tools used in soldering and desoldering.



HCS13-22

Figure 5-2. Thermal strippers.

033. Identify the proper use of some of the specialized tools used in soldering and desoldering.

Insulation Strippers. Stripping the insulation from a wire is one of the first steps you take when you are preparing a wire to be soldered. Great care is needed to ensure that the wire is not cut, nicked, or scraped in the process. For this reason, use a thermal stripper instead of a precision-cutting stripper.

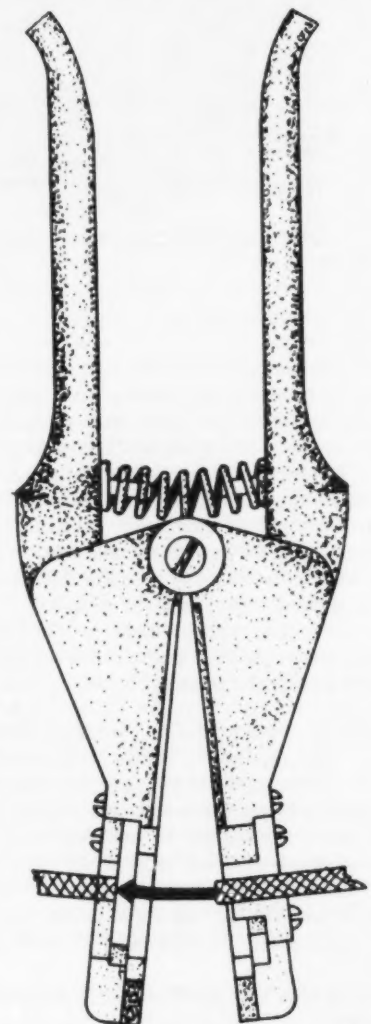
Thermal strippers. Use thermal strippers (fig. 5-2) when possible and particularly on wire size 22 AWG (American wire gauge) and smaller. The stripper should have a controllable heat output to prevent blistering or melting the insulation excessively. Use an exhaust hood and fan ventilation system to dispose of toxic fumes when you are stripping such insulation as Teflon, polytetrafluoroethylene, or polyvinyl chloride. Since it is not always practical to use a thermal stripper, the next best stripper is the precision-cutting type.

Precision-cutting strippers. Precision-cutting strippers (fig. 5-3) can be used on wires larger than 22 AWG. Use these strippers to strip glass or braided insulation but not to strip Teflon-insulated wire. Precision-cutting strippers are not adjustable, but the blades are replaceable. These strippers should be checked periodically for proper operation.

Bending Tools. Wire-bending tools should have smooth bending surfaces so you can bend the component leads without nicking, scraping, or damaging them (fig. 5-4). You can use standard needlenose pliers for bending wires and component leads, providing the jaw tips are encased in covers of copper tubing, as shown in figure 5-4.

Thermal Shunts. During a soldering operation, use thermal shunts or heat sinks (fig. 5-5), as necessary, to protect heat-sensitive components, such as semiconductors, crystal devices, meter movements, and insulating materials, from heat damage. A thermal shunt should be made of a material, size, shape, and design that permits rapid application and removal with minimum interference to the solder procedure and rapid heat removal from the area being soldered. Hold thermal shunts in place by friction or spring tension, which will prevent damage to the wire surface, the insulation of the wire, and the component being soldered.

Cleaning Tools. Cleanliness is the key to reliable soldering. Remove all dirt, grease, and oxidation from the surface to be soldered. Clean the component leads before soldering. An efficient cleaning tool is shown in figure 5-6.



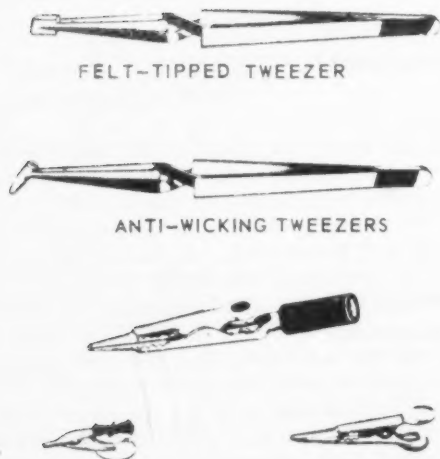
NGE10-15

Figure 5-3. Precision-cutting strippers.



NCS13-25

Figure 5-4. Wire-bending tools.



FELT-TIPPED TWEEZER

ANTI-WICKING TWEEZERS

NCS13-7

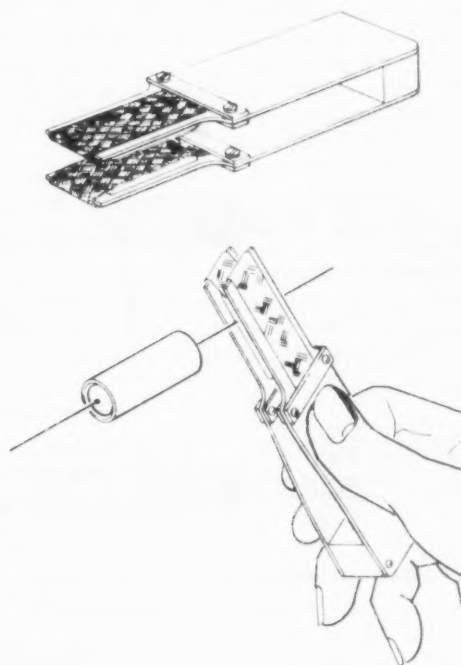
Figure 5-5. Thermal shunts.

For cleaning soldered areas, use a medium-stiff natural or synthetic bristle brush or a lint-free, industrial cleaning tissue. Dip this into an approved cleaning solvent and use it to remove excess flux after the solder solidifies. You can use a pencil-style, white typewriter eraser for cleaning copper-clad unplated boards and for removing gold plating from printed-circuit pads and some components leads (fig. 5-7). Avoid the use of knives, emery cloth, sandpaper, and other abrasives that can nick and scratch component parts.

Soldering Aids. Figure 5-8 illustrates three soldering aids that are useful in desoldering connections. Use the slotted ends to lift the ends of wire and component leads from the terminals. Use the pointed ends to remove solder from terminal holes and slots. You can use the bristle brush to remove molten solder, but you must be careful to keep from splattering the solder. Don't use wire brushes for this.

Don't use the soldering aids to exert force in security testing. A good visual inspection can determine the quality of a properly bonded solder connection. Bending or pulling wires to ascertain the security of the connection can present a serious reliability hazard and is acceptable only when a visual inspection is not possible.

Soldering Irons and Guns. The careful selection of an iron of the correct size, shape, and wattage is a prerequisite for reliable soldering. The size and shape of the iron and tip should permit soldering with maximum ease and with a minimum danger of damage to the surrounding area.



NCS13-13

Figure 5-6. Braided cleaning tool.



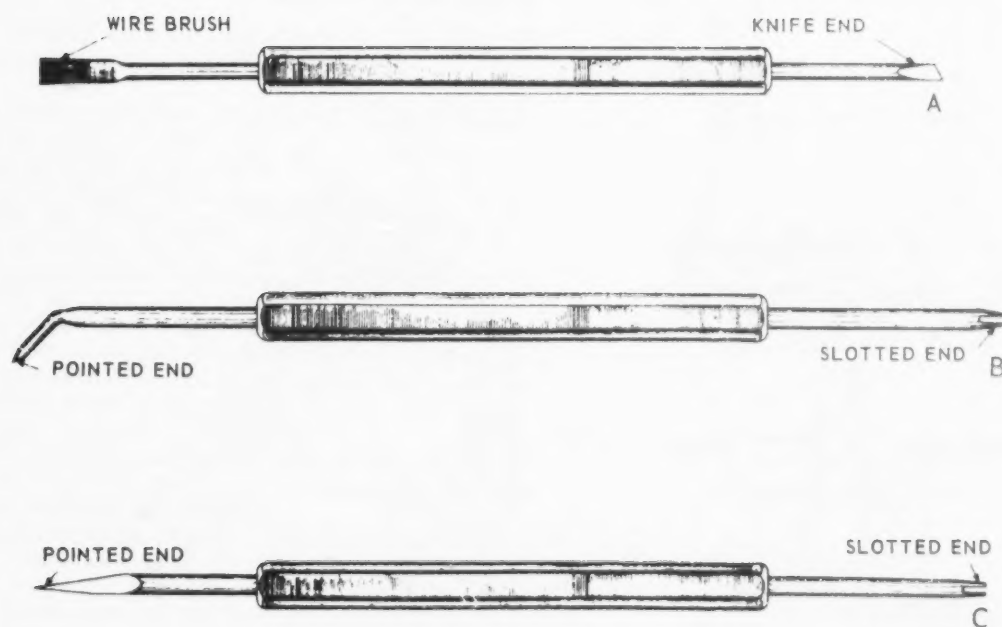
TYPICAL PENCIL-STYLE,
TYPEWRITER ERASER



CLEANING OPERATION FOR PRINTED
CIRCUIT PAD

NCS18-289

Figure 5-7. Typewriter eraser cleaning tool.



NCS13-6

Figure 5-8. Soldering aids.

Soldering irons and guns are available in a variety of sizes and wattage ratings. Determine whether a soldering iron or a soldering gun is more suitable for the type of soldering operation to be done. Use a variable voltage supply to control the temperature of the iron when you solder printed circuits. A variable voltage supply also has advantages in many other soldering applications.

The size and shape of the connection being made determines, to a large extent, the wattage ratings of the iron or gun. Ratings of 25 watts to 100 watts are most commonly used in this career field. Ratings of 100 watts to 450 watts are generally used for soldering large terminals and metal chassis.

Exercises (033):

1. Why are thermal strippers useful for preventing blistering or excessive melting of insulation?
2. Why should bending tools have smooth, bending surfaces?
3. What can you use to clean gold plating from printed-circuit pads?

5-3. Proper Soldering Techniques

Always remember that a neat and orderly work area reduces confusion and contributes to safety and high quality work. This section will cover some of the proper soldering techniques to aid you in learning to solder.

034. Identify proper soldering techniques and some of the safety precautions used.

Work Areas. Occasionally, good work may be turned out with poor tools in a poorly organized work area, but this is an exception. Using the wrong tool or failing to prepare your work area almost invariably increases the time you need to complete the job, the possibility of poor quality work, and/or your chances of being hurt. Since a large percentage of soldering work is done on a workbench, it only makes sense to start the job with a neat, uncluttered work area. Have out only those tools and devices you'll need for the job. In those cases where you have to solder in or on the equipment, the same ideas apply. Keep all areas clean and neat. The following is a list of safety precautions you need to know and use when soldering. They are:

a. When soldering irons are not in use, place them in appropriate holders. This practice prevents the iron from burning the workbench or falling onto the floor. In either case, the iron is a fire and personal hazard, and the heating element of an electrical soldering iron may be damaged by a fall.

b. Place the soldering iron where you don't have to reach across or around it. When you pick it up, always remember to look first at the soldering iron in order to avoid touching the barrel.

c. Do not test the heat of a soldering iron by holding it near your face. Test it with solder while holding it away from your body. You will avoid injury from sputtering particles of solder or flux.

d. Do not attempt to remove molten solder from a soldering iron by flipping. Use a rag, damp sponge, or canvas pad to wipe solder from the tip.

e. When you must carry a hot soldering iron, do not let the cord drag on the floor, as it can catch on equipment and drag the iron through your hand.

f. Never use a file that is not fitted with the proper handle.

g. When desoldering a wire, make certain there is no tension or spring in the wire. Wear safety glasses during this operation to keep hot solder out of your eyes.

h. When you are skinning or pulling wire with pliers, never pull toward your face. Under no circumstances use the pliers at eye level or in close proximity to your face.

i. When you are cutting wires, keep the open side of the cutter away from your body. Keep your wires in your own area, and prevent outside wires from entering your area.

j. To avoid electrical shock, disconnect all power and discharge the circuit before working on a chassis.

Work Preparation. Now that we've covered the work area pretty well, let's look at some of the areas we may be required to solder on. This career field has such a wide variety of equipment, you may find yourself soldering on many different types of electronic equipment. Some equipment is very old while others use the newer microelectronic circuitries. The older circuitry can usually be soldered with some heavier (higher wattage) soldering irons. These irons will destroy the newer microelectronic circuitries because of the heat alone. Because of such variations in our equipment, you must always be alert and take care when preparing to solder. To prepare for the work, you must first decide what type of soldering iron and solder you'll need. The work surfaces may also need special preparation. These things and more must all be taken into consideration before you solder. The following sections of this chapter will cover these areas in more detail.

Exercises (034):

1. State the benefits of a well-organized work area and proper tools.
2. What is the recommended method of removing excess molten solder from a soldering iron?
3. If you are working on a chassis with power removed, why should you discharge the circuit before you make any soldered connections?

5-4. Soldering

Soldering is a physical skill that depends primarily on experience. No amount of written material can give you that experience. However, we can advise you on the general knowledge needed to perform the task.

035. Describe the chemical action that takes place during the soldering process.

Soldering Process. Before going into specific procedures about soldered connections, let's look briefly at the chemical action that takes place during the soldering process.

In its molten state, solder attaches by a metal solvent or an intermetallic solution action. We can illustrate the solvent or solution action with table salt. Ordinarily, table salt has to be heated to 1,488°F before it melts. However, when you add a little water to the salt, it melts easily without any heat. The action of molten solder on a metal such as copper can be compared to the action of water on salt. The solvent or intermetallic solution action chemically dissolves part of the metal surfaces to be joined at temperatures well below the melting point of the metals being soldered.

A soldered joint is chemical in character rather than purely physical because the attachment is formed in part by chemical action rather than by mere physical adhesion. Because of the solvent action, the properties of the soldered joint are different from those of the original solder, and you have a new and different alloy between the respective metals.

This new metal contact provides metal continuity while an unsoldered contact is discontinuous. When two metals are soldered together, they behave like one solid metal. In contrast, if they are bolted, wired, or otherwise only physically attached, they never make good electrical contact because of the insulating film on the surfaces of the metals.

Exercises (035):

1. Describe the metallic solution action that takes place during a soldering operation.
2. Describe the advantage the soldered connection has over the wired or bolted connection.

036. Identify selected steps in the preparatory maintenance required for a soldering iron.

Making Soldering Connections. Research has shown that the best solder joints are produced within a narrow range of temperature and application time. Joint

temperatures of 500 to 550°F applied from 1 to 2 seconds produce the strongest connections. Therefore, you should select an iron with the size, wattage, and shape needed to provide these conditions. The iron tip should be able to heat the joint to soldering temperature rapidly. The amount of heat needed in the tip implies that the mass of the tip is larger with respect to the mass of the metal being heated for solder application.

Still, the tip must not be so large that it obscures your vision or damages the adjacent parts or wire insulation. Also, the tip shape (such as spade, chisel, or pyramid) should be appropriate for the job you are doing. It is good practice to keep an assortment of spare tips and to change the tip as necessary to meet the requirements of various types of work.

As we stated earlier, the variable voltage soldering iron should be used on printed circuits, and it can be advantageous in many other soldering applications. By the proper selection of tips and voltage adjustments, you can use a single 50-watt, pencil-type iron for soldering both miniature printed circuits and relatively large terminals. Thermostatically controlled irons require less skill in judging heat, but they are less versatile.

The unplated copper tip produces good results and is widely used in our career field. Because of pitting, burning, and oxidation, an unplated copper tip requires some preparatory maintenance before each use. The following is a brief description of the preparatory maintenance that may be required.

- a. Ensure that each face of the tip is flat and without pits, facets, scratches, or burrs.
- b. Ensure that each face will form a 45° angle with the center line of the soldering iron tip.
- c. Ensure that the iron's tip is square when it is viewed from the face side.

NOTE: For unplated tips only. If any one of the conditions listed in steps a, b, or c does not exist, the tip can (and should) be reshaped. A file can be used for reshaping unplated tips.

- d. Once the tip is properly shaped, ensure that it is correctly attached to the holder (iron).
- e. Tin the tip with solder.

There will be occasions where you'll have plated tips to use for soldering. In this case, you will *not* use a file or abrasives to clean or reshape the tip. The tips come in assorted styles and shapes and are designed for specific jobs. All you'll have to do is attach the selected tip to the iron and clean it by wiping it on a damp sponge or soft material before use. Once cleaned, tin the tip as usual and proceed.

On any soldering iron tip, always wipe off all excess solder before storing. Tips should be stored with a small amount of solder on them to prevent oxidation.

With the tip dressed and cleaned, you are ready to start soldering operations. Normally, this is simply a matter of applying heat and solder to a connection and then cleaning off the excess flux when the joint cools. At other times, you will be faced with the problem of desoldering a joint,

mounting parts or terminals, terminating shields, and repairing multiconductor cables. We will look at these in more detail later.

Exercises (036):

1. In selecting a soldering iron tip, what three conditions must you consider to make the best solder joint?
2. Explain the size restrictions you should consider in selecting a soldering iron tip.
3. How should an unplated soldering iron tip appear when viewed from its face?
4. Why should you store tips with a small amount of solder on them?

5-5. Desoldering

Since most of the soldering jobs in the Automatic Tracking Radar career field are the removal, replacement, and repair of components, you must know desoldering techniques as well as soldering techniques.

037. Identify the basic desoldering techniques of wicking and sniffing.

Basic Desoldering Procedures. Although there are other techniques for desoldering, we will discuss only the *wicking* and *sniffing* techniques. Each of these techniques is very effective in removing the old solder from a previously soldered joint.

Wicking. Figure 5-9 shows some typical materials that can be used to make a wick. You can make an effective wick by stripping the braided shield from a piece of coaxial cable or by removing the insulation from a piece of multistrand wire.

This is the principle of wicking: if you apply heat to a well-saturated rosin wick, the solder will flow readily into the rosin area, leaving the terminal to which it was previously affixed. Almost as if by osmosis, the solder travels into the saturated wick.

In preparing your wick, use a wire size no larger in diameter than the pad size that you will be wicking solder from. This is important because if you let the wick touch the board, it will "frogeye" the material on the board.

Refer to figure 5-9,A, and the list below for the procedures used in making an effective wick.

- a. Remove 6 to 8 inches of shield from coaxial cable and flatten it with a bending tool.
- b. Dip about 2 inches of the wick into liquid solder flux.

Be sure the liquid flux rosin is the same as the rosin you intend to use in your repair work.

c. Tin the end of the wick by applying heat and a thin coat of solder.

d. If you use multistrand wire, strip about 4 inches of insulation from the wire.

e. Flatten the wire slightly, keeping the strands in place.

f. Dip the wire in liquid rosin and tin the end.

Now that you have an effective wick, let's see how to apply it, (refer to fig. 5-10).

a. Place the wick on top of the solder joint to be removed.

b. Place the iron tip on top of the wick. When the iron melts the solder, it will flow into the wick.

c. As the wick becomes saturated with solder, clip off the end of the wick, and repeat the operation until you have removed all the solder from the joint.

Sniffing. In this method, you use a tool like a syringe (refer to fig. 5-11). This tool is made from material that will not bond to solder. Although this method is not as highly recommended as wicking, it is effective.

The sniffer, or sometimes called "solder sucker," uses the force of air pressure to remove the molten solder. You use the sniffer as follows:

a. Squeeze the air out of the rubber ball at one end of the sniffer.

b. Keeping the ball depressed, place the pointed end of the sniffer next to the solder to be removed.

c. Heat the solder with a soldering iron, keeping the tip of the iron in the solder and *not* on the sniffer.

d. Slowly release the pressure on the sniffer ball. As the air enters the tube, it will pull the molten solder in with it.

e. After you have drawn the solder from the joint, remove the sniffer. Depress the tube again to remove the solder from the sniffer.

Each of these methods removes solder from a joint. In each method, you must exercise caution because of the heat, component reaction to heat, and possible damage to base materials and adjacent components.

Exercises (037):

1. Briefly explain the principle of "wicking."
2. Outline the steps involved in the "wicking" process.
3. Briefly explain the principle of "sniffing."
4. Of the two methods of solder removal, which is preferred?

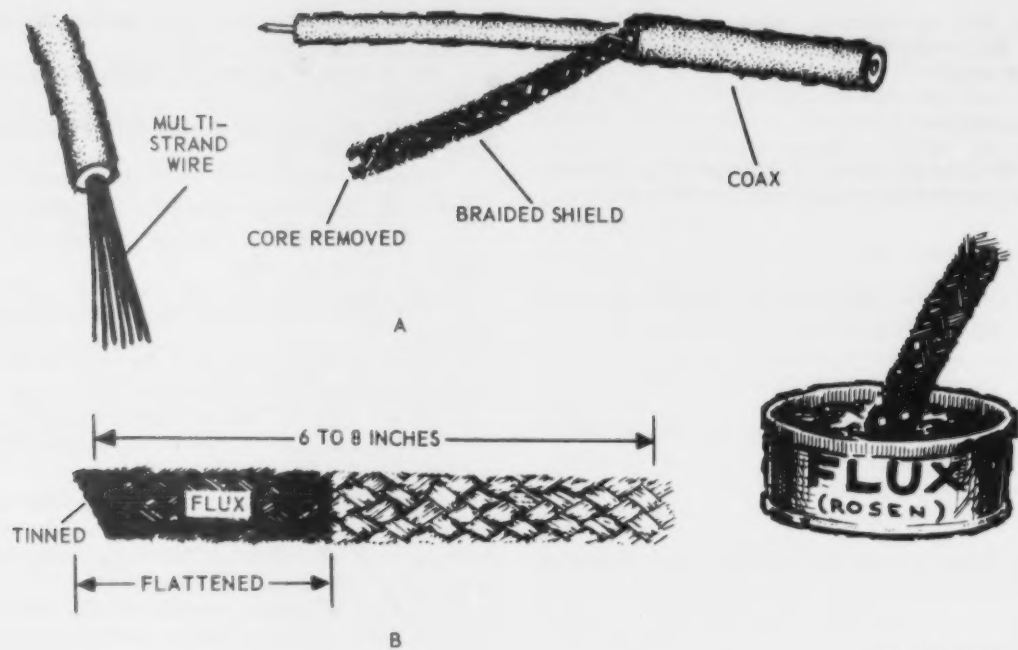


Figure 5-9. Wicking tools.

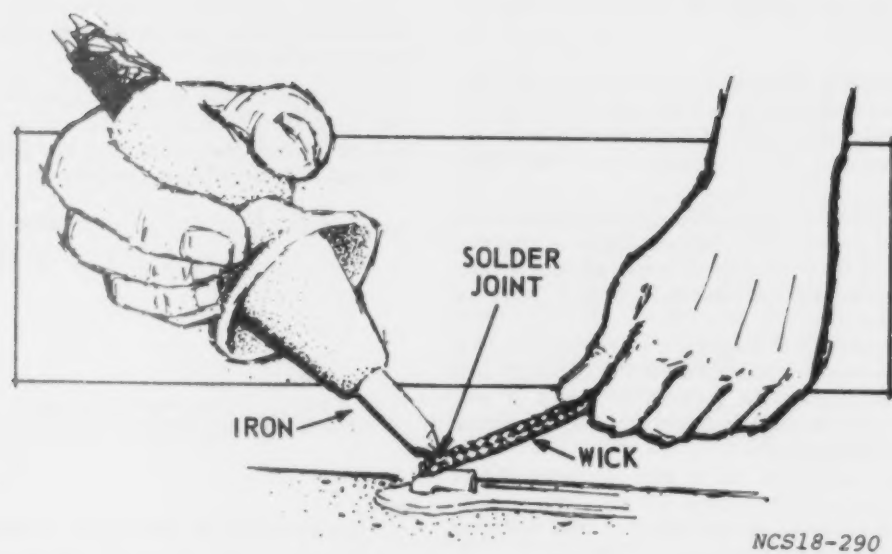
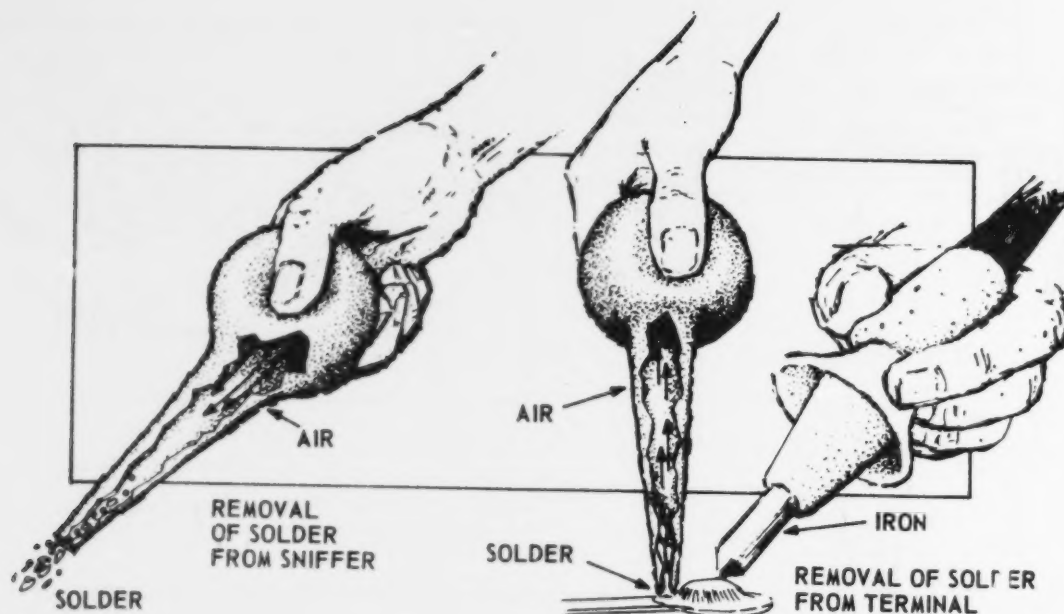


Figure 5-10. Wicking application.



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Figure 5-11. Sniffing application.

5-6. Applications

Up until now, our discussion on soldering has been fairly general. Now, we will turn to some specific applications of soldering techniques.

038. Identify some of the procedures used to prepare a wire or a component lead for a soldering operation.

Preparing Conductors and Part Leads. To strip insulation, you should use one of the specialized tools discussed earlier. If you are planning to strip many wires of the same size, we recommend that you tape over the unused holes in the precision wire stripper to avoid possible damage to the wire strands.

If you are using thermal strippers, be sure to remove the burned insulation residue. Remember, thermal strippers require ventilation. Inhaling the vapors from the breakdown of polymerized organic insulation can cause polymer fume fever.

If the stripping operation separates or discharges the strands, restore them to their original lay before tinning. If you nick the strands or damage the insulation, do not use the wire in a soldering operation.

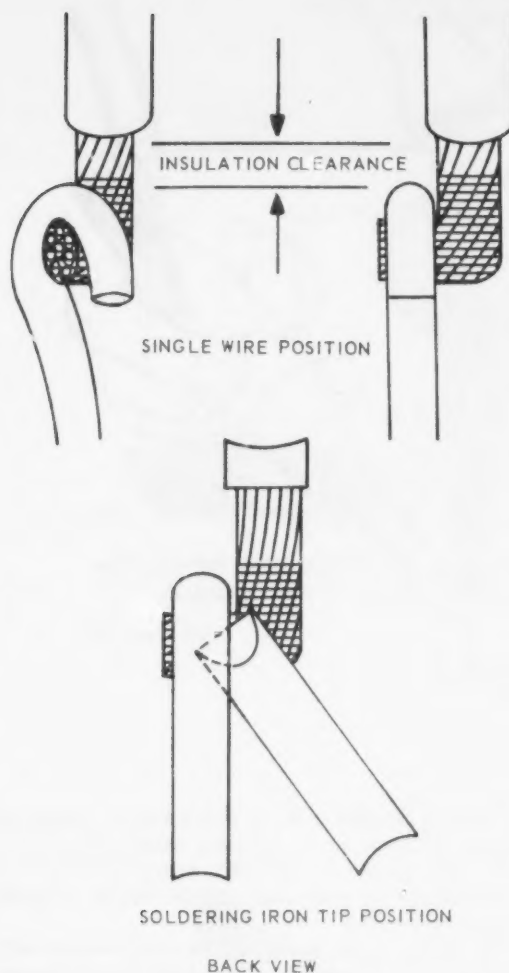
Insulation gap. The end of the insulation should be far enough from the solder joint so that the insulation cannot become embedded in the solder, but not far enough to permit a short circuit between two adjacent wires. In general, the length of the gap should be equal to approximately the wire's diameter (fig. 5-12).

Cleaning the part lead. To assure a good wetting action between the parts to be soldered, remove all impurities, such as dirt, grease, or oxide film. Also remove any surface contamination or corrosion formed during processing, storage, or handling.

The tinning of the conductor wire should extend only far enough to take advantage of the depth of the terminal or solder cup. Figure 5-13 illustrates the correct method for tinning. The solder applied during the tinning process should penetrate to the inner strands of a multistrand wire. If you tin the wire outside the terminal or solder cup where flexing may occur, it will cause stiffness and the wire could break.

Exercises (038):

1. How should a properly stripped multistrand wire look?
2. What is the normal length of a gap between the insulation and terminal?
3. State the recommended procedures for preparing a multistrand conductor for a soldering operation.



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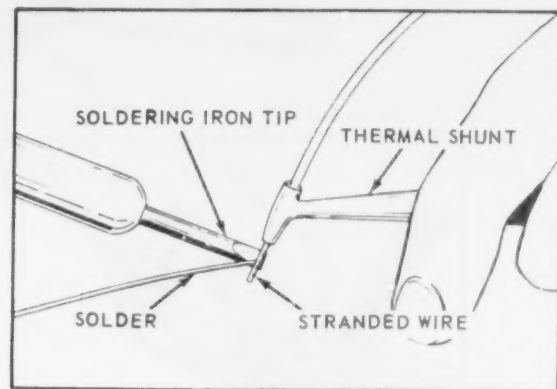
Figure 5-12. Proper insulation clearance for single wire position and soldering iron tip position.

039. State the proper method for connecting a conductor to a specific type of terminal.

Types of Terminals. The four most common terminals found in our equipment are bifurcated, turret, flat perforated, and hook. Let's briefly consider the proper method of connecting a conductor to these terminals.

Bifurcated terminal connections. The common methods of inserting conductors into a bifurcated terminal are called the bottom route and the side. If a top entry must be used, provide solder fillets to both prongs of the terminal.

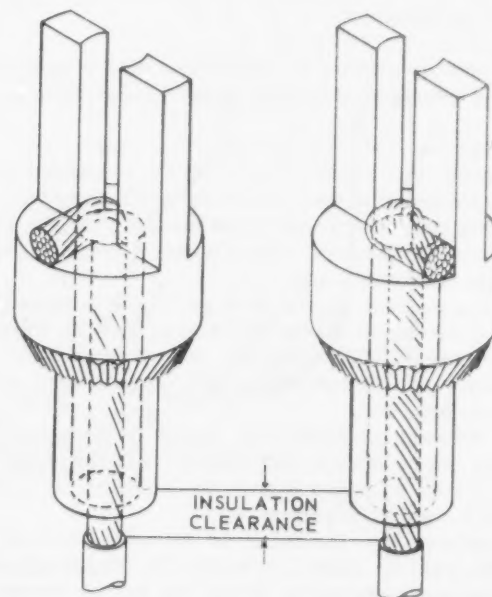
For bottom entry, insert the tinned conductor into the terminal from the bottom, as shown in figure 5-14. Strip the conductor far enough so its insulation does not extend into the barrel (approximately 1/32-inch clearance is recommended). Bend the wire end to lie flush against the shoulder or one of the posts.



NCS13-8

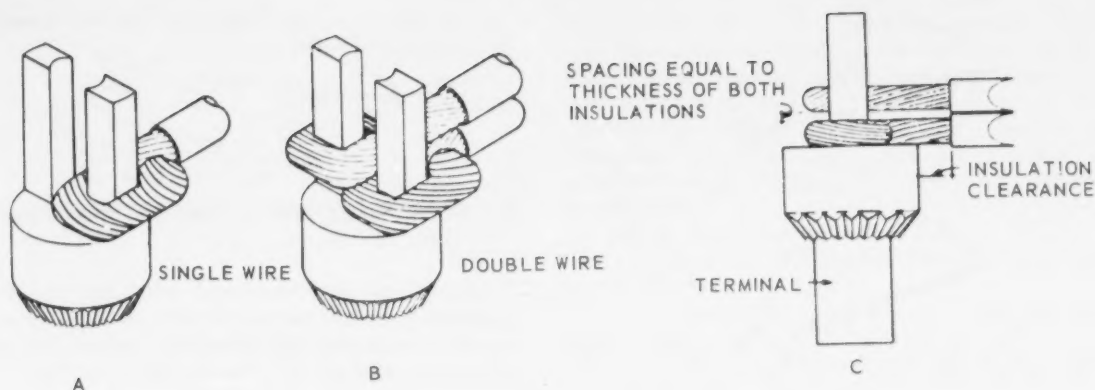
Figure 5-13. Correct method for tinning wire.

For a side entry, bring the tinned wire end through the gap and bend the wire flush against the post, as shown in figure 5-15,A. Bend a second wire in the other direction to lie flush against the other post, as shown in figure 5-15,B. Alternate additional wires in the same way. You may fill the gap, but under no circumstances should the last wire extend beyond the top of the posts. If the wires are smaller than 26 AWG, you may wrap them one-half turn around the posts if there is enough side clearance.



NCS13-21

Figure 5-14. Bottom route connection of bifurcated terminals.



NCS13-26

Figure 5-15. Side route connection of bifurcated terminals.

If the conductors must be inserted from the top, the wire should fill the space between the posts so that a fillet is formed to each post. A wire conductor of small diameter may be bent in a U-shape (fig. 5-16), provided the combined diameter is sufficient to fill the gap. A filler (solid or stranded) may also be used to fill the space.

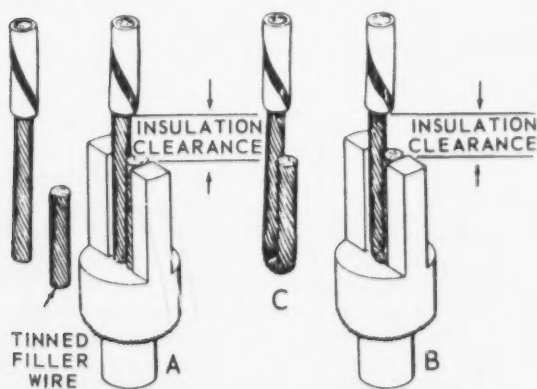
Turret. Turret terminals (also called grooved and stud terminals) usually function as tie points for conductors and components in communications-electronics equipment. The terminals are normally divided into an upper grooved section and a lower grooved section. You should terminate your conductors on the lower section and the leads of small components (resistors, capacitors, etc.) on the upper section. Follow this arrangement, as far as feasible, on turret terminals that have only one section rather than two.

In making wire connections on turret terminals, bend the tinned conductor into a loop of approximately one-half

turn, slip it over the glide spot, and place it snug against the shoulder (fig. 5-17). You may wrap wires smaller than 26 AWG to a full turn, but do not let them overlap. Do not wrap wires larger than AWG 26 more than three-fourths turn.

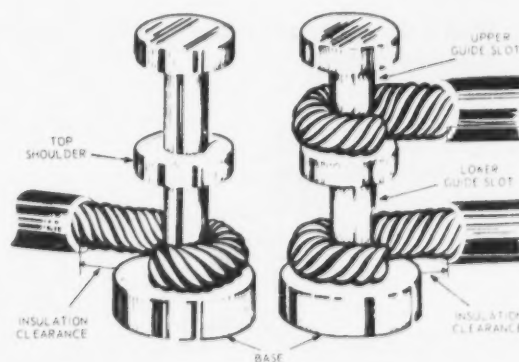
When you are using hollow-post turret terminals, insert the tinned end of the wire through the swagged end of the terminal, allowing 1/32-inch insulation clearance. Bring the tinned end of the conductor out of the side slot at the top and wrap it as required for the side route.

Flat perforated. Flat perforated terminals are flat metal strips of varying thicknesses and lengths with a hole through one end to accept conductors and the other end mechanically connected to equipment components. Some of the more common applications for this type terminal are as connecting points for tube sockets, jacks, and signal lamps.



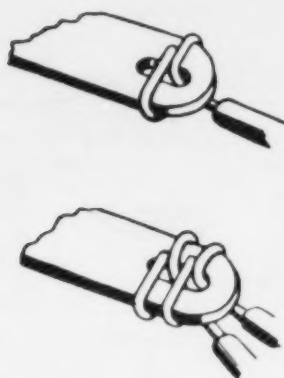
NCS13-20

Figure 5-16. Top route connection of bifurcated terminals.



NCS13-17

Figure 5-17. Turret terminal connections.



NCS13-11

Figure 5-18. Correct wrap for flat perforated terminals.

When attaching wires to perforated terminals, use a minimum of one full wrap and a maximum of $1\frac{1}{2}$ wraps. Figure 5-18 illustrates a $1\frac{1}{2}$ wrap. If space is insufficient, as with most miniature tube sockets, make a mechanical connection by feeding the wire through the terminal hole, using a 180° wrap (fig. 5-19) and then firmly crimp the wire.

Hook and eyelet. This type of terminal is most often found on relays and lamp bases. When attaching wires to the hook or eyelet terminal, you should wrap them around the terminal a minimum of one-half of a turn and a maximum of three-fourths of a turn. Figure 5-20 illustrates single-wire and double-wire connections on a hook terminal.

Exercises (039):

1. Give the correct procedures for making a fillet for a top entry connection on a bifurcated terminal.
2. What is the recommended insulation clearance on the bifurcated terminal?



NCS13-12

Figure 5-19. Crimp (for limited space only).

3. On which section of the turret terminal should your conductors be terminated?

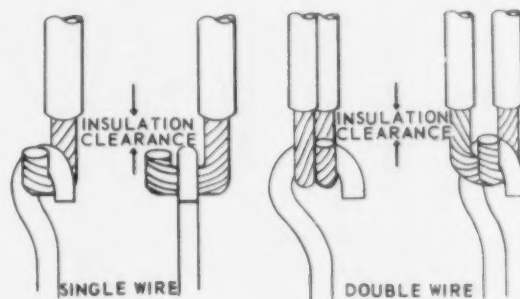
5-7. Soldering Printed Circuits and Microelectronic Circuits

Because of their increased reliability, economical operation, increased packing density, and reduced weight, printed circuits and microelectronic circuits are used in electronic equipment in an ever-increasing number.

040. Identify selected precautions associated with printed-circuit assembly repair.

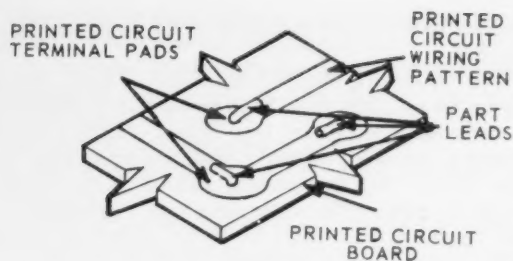
General Precautions. Certain precautions are necessary in soldering printed-circuit boards because of the delicate nature of the wiring material and wiring-to-board bonding and the heat sensitivity of the miniaturized parts. When you solder printed-circuit boards, observe these general precautions.

- a. To reduce the amount of heat required for the soldering operation, use a solder of smaller diameter ($1/32$ -inch maximum) and low-melting point.
- b. Use a 50-watt iron or less.
- c. Use grounded soldering iron equipment or ground the soldering iron tip, preferably with alligator clip heads. (The leakage current of some soldering irons is enough to damage transistors and small semiconductor devices.)
- d. Use enough thermal shunts to protect heat-sensitive devices sufficiently.
- e. Make sure that the total time of heat application does not exceed the time required to melt the solder and properly fuse the solder with the terminal pad and component lead. When you make a solder connection, apply the smallest amount of heat needed to produce a satisfactory connection.
- f. If you have trouble soldering a satisfactory connection, stop and let the connection cool completely before you attempt to resolder.



NCS13-19

Figure 5-20. Hook terminal connections.



NCS13-27

Figure 5-21. Clinched lead terminals.

g. Remove flux and flux residues from the solder connections within 90 minutes after the completed connection has cooled. (Remove them with isopropyl alcohol or aliphatic naphtha.)

h. And above all else, check to see if the solid-state device requires the use of electrostatic discharge procedures.

Exercises (040):

1. What is the maximum diameter recommended for the solder used in printed-circuit repair?
2. Why should the soldering iron tip be grounded during the repair of printed-circuit boards?
3. Describe the proper procedure to follow if you have difficulty in soldering a connection.

041. Name the two types of part lead terminations and compare their uses.

Part Lead Terminations. Part leads are terminated on printed-circuit pads using clinched leads (standard) or unclinched leads (special).

For a clinched lead termination (fig. 5-21), the part lead extends through the printed-circuit board for a minimum of the printed-circuit pad's radius and a maximum of the pad's diameter. The part leads are clinched in the direction of, and parallel to, the printed-circuit wiring pattern. The clinched lead should contact the printed-circuit pad; however, an angle between the clinched lead and the printed-circuit pad of up to 30° is acceptable.

The unclinched lead termination (fig. 5-22) is used in special cases where parts are light and there is no stress on the solder connection. For this termination, the part lead should extend through the circuit board for a maximum

distance that does not protrude beyond the pad circumference, when viewed vertically. Normally, all parts using the unclinched termination are rigidly secured to the printed-circuit board by suitable mounting clamps or an epoxy-resin compound.

Satisfactory solder connections for clinched and unclinched lead connections and for clinched and unclinched lead terminations have the following characteristics.

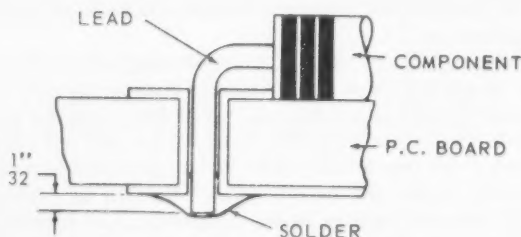
- a. The contour of the part lead is visible.
- b. A concave fillet is formed between the part lead and the terminal pad.
- c. The concave fillet blends into the completely wetted (solder fused smoothly into all portions) terminal pad.
- d. The solder is smooth and shiny and has no voids or gaps.
- e. The color of the rosin residue from heated flux is from light amber to a medium brown after the solder operation. (This rosin residue must be completely removed after the connection has cooled.)

Exercises (041):

1. Name the two types of lead terminations recommended for printed circuits.
2. How does the use of the second lead termination differ from the use of the first type?

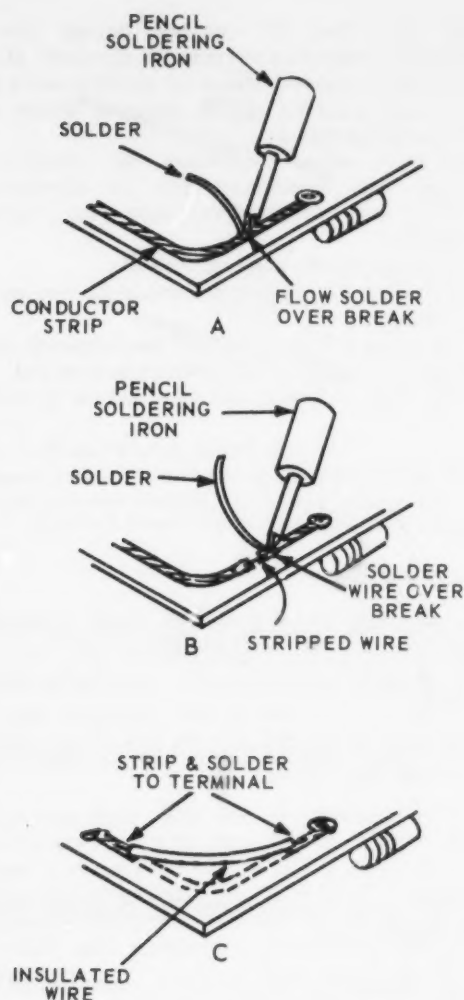
042. State proper procedures for repairing printed circuit boards.

Repair. Before you begin to repair printed circuits, read the system's technical orders to learn the degree of maintenance authorized on your printed-circuit boards. Also determine whether there are any quality control directives governing the methods of repair. Here are some of the most common discrepancies and repair procedures associated with printed-circuit boards.



NCS13-28

Figure 5-22. Unclinched lead terminals.



NGE10-36

Figure 5-23. Methods of repairing broken conducting strips.

Repairing damaged strips. If, during troubleshooting, you find a break in the conducting strip of a printed-circuit board, you or your supervisor must determine what course of action to take. Whether you repair or replace the printed-circuit board depends upon the amount of damage to the board and the level of maintenance authorized in your organization.

Generally, if the break in the conducting strip is small, you should lightly scrape away any coating covering all conductive strip to be repaired. If possible, clean the area with a pencil-style typewriter eraser, or you can use a firm bristle brush (not a wire brush) and an approved cleaning solvent. Repair the broken area of the foil by flowing solder over the break as shown in figure 5-23,A. If there is any indication that the strip may peel or if the break is larger than a crack, bridge the area with a section of bare wire, as shown in figure 5-23,B, and apply solder along the entire length of the wire to bond it solidly to the conducting strip.

Keep the solder within the limits of the strip that you are repairing.

If the conducting strip is burned out or fused, cut and remove the damaged strip. Then connect an insulated wire across the break and solder. (See figure 5-23,C.) If the strip terminal is removed, instead of soldering to the strip, as in figure 5-23,C, use an insulated standoff at the damaged terminal or replace the whole strip with a conductor strip from a printed-circuit board repair kit. Repair kits contain instructions for the replacement of printed-circuit board conductor strips.

Component replacement. The job of removing and replacing defective components on a printed-circuit board is not difficult, but it does require a certain amount of care because of the fragile construction of the board. The misuse of a soldering iron or the use of improper handtools can result in the complete replacement of a printed-circuit board instead of merely a component on the board.

The tools used to repair metal chassis are not practical in the repair of printed circuits. Many different tools are used for special jobs, but only those most frequently used are given below:

- a. Printed-circuit board vise.
- b. Heat sinks.
- c. Longnose pliers.
- d. Soldering aids.
- e. A 20- to 40-watt soldering iron.
- f. Assorted soldering tips.
- g. Stiff bristle brush.
- h. 60:40 solder—63:37 solder preferred for solid-state and microminiature circuits.
- i. Wiping cloth or sponge.
- j. Rosin paste.

The usual steps in the removal and replacement of a defective component are listed below. Remember that these are general steps and in certain instances will not apply to your particular situation.

Secure the printed-circuit board in a repair vise before you do any work on it. With the board in the vise, you are ready to begin removing the defective components. Grasp the lead on the end of the component with longnose pliers. If you are not sure that the component is defective, place a heat sink as near as possible to the body of the component.

Apply the soldering iron to the component lead (37-watt soldering iron recommended), being careful not to touch the eyelet through which the lead is soldered. When the solder within the eyelet begins to flow, gently pull the lead through the eyelet with the longnose pliers. Repeat this procedure on the other component lead. Clean both eyelets before the new component is installed.

After cleaning the eyelets on the board, you should be ready to install the replacement. If you have not previously shaped the leads of the new component, do so now. Insert the component lead through the eyelet, and hold it in place with a pair of longnose pliers. Remember, use a heat sink if your component is affected by heat. With the lead in place, apply a soldering iron to the component lead and allow solder to flow into the eyelet. Then repeat the procedure on the other lead.

After soldering the component, inspect your work for any defects. Listed below are some checks that will help you. As you become more proficient in the maintenance of printed-circuit boards, you will be able to add to this inspection list:

- Check the component for security.
- Check the solder head—it should be shiny and smooth.
- Check the printed wiring (foil). The heat of your iron may have separated the printed wiring from the board.

Exercises (042):

1. What procedure should you use to repair a small break in the conducting strip of a printed circuit?

2. What should you do if the conducting strip shows signs of peeling?

3. What is the first thing you should do before replacing parts on a printed-circuit board?

043. State emergency repair procedures of a printed-circuit board.

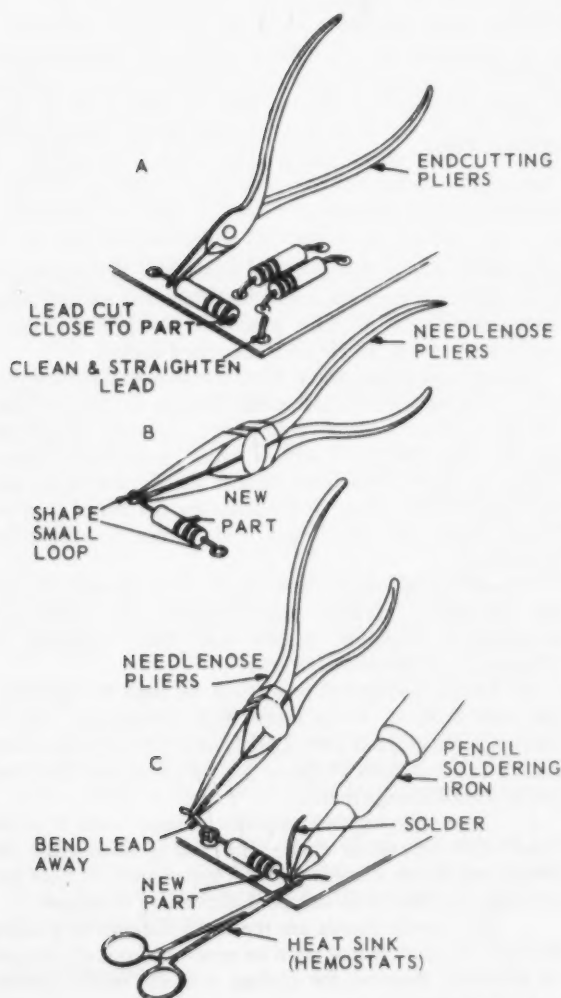
Emergency Repair. In many instances, you must use timesaving techniques and procedures in the emergency repair of electronic components. In an emergency, it is desirable to avoid disassembling the unit more than is absolutely necessary to expose the defective part for both testing and repair. You can often do this by merely removing the cover of the assembly.

There are numerous methods of emergency repair and the repair situation can vary widely as a result of the malfunction. We obviously cannot present all methods here. Therefore, we will limit our discussion to just one example of emergency repair. The following steps show you how to remove and replace a defective component by using its leads.

After you have found the defective component in the printed-circuit board, cut its leads as close as possible to its body and remove it (fig. 5-24,A). Straighten and clean the leads remaining on the board from the removed component. Obtain a replacement component and fashion a small loop at both ends (fig. 5-24,B.) Make the loops so that the new part can easily slip over the defective component's leads. Secure the connections by bending the old leads away from the part, as shown in figure 5-24,C. Place a heat sink clamp on the lead from the board to prevent that lead from becoming unsoldered. Solder the lead and the component together (fig. 5-24,C). Make sure that the old leads have not been disconnected from the circuit board during the soldering operation.

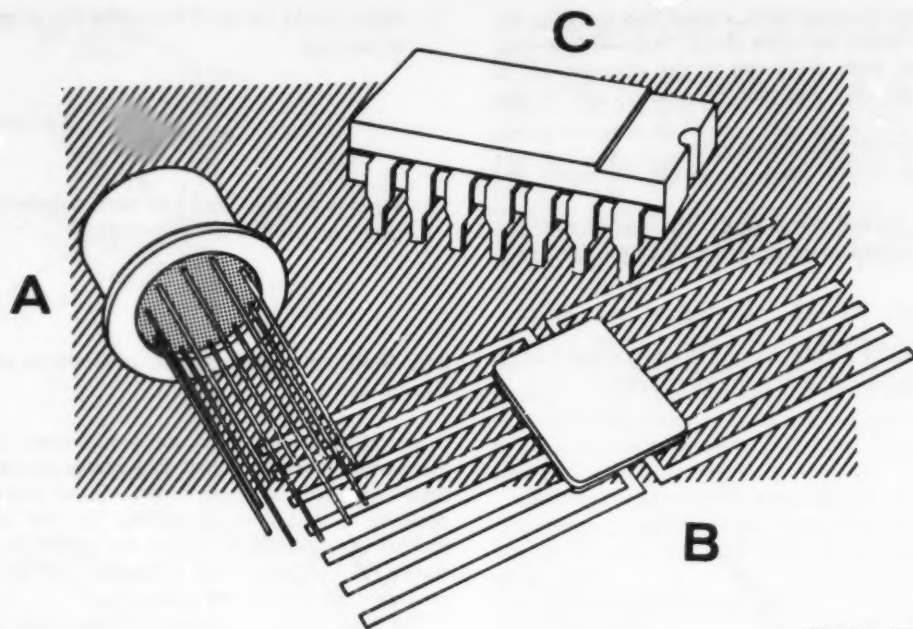
Exercises (043):

1. Where should you cut the leads on the defective part during emergency repairs on a printed-circuit board?
2. Briefly state the procedure for installing a new component using the emergency repair method.



NGE10-18

Figure 5-24. Emergency repair.



NCS13-53

Figure 5-25. Microelectronic packages.

044. State the procedures for preparing and installing an integrated circuit on a printed-circuit board.

Installing Microelectronic Integrated Circuits. Microelectronic integrated circuits are miniaturized devices containing elements fused together to form passive or active electronic circuits. These circuits are potted or hermetically sealed in small packages. Like the transistor when it was first introduced, these circuits caused some confusion until procedures for their installation, testing, and replacement were established.

If properly installed, the microelectronic device withstands a great deal of abuse and vibration, but the best engineered device in the world is no better than the solder joint that connects it into the electronic circuit.

In maintenance work, you must treat a package of microcircuits as you would any other discrete component, exercising, of course, the kind of care in handling that these packages require. The usual packages for microelectronic circuits are: (1) a TO package (fig. 5-25,A); (2) a flat pack (fig. 5-25,B); and (3) a standup flat pack (fig. 5-25,C). Many different techniques are used to secure these devices to a printed-circuit (PC) board, such as gap welding, resistive soldering, thermal agitation, electron beam bonding, reflow bonding, and the lapflo system. (The lapflo system is discussed later in this chapter).

TO packages. There are several different types of packages used for encasing microcircuits. The TO package shown in figure 5-25,A, is the most widely used. This type of packaging should be familiar to you because of its extensive use as a case for transistors. However, as a result

of modern day technology, the content of the package is quite different from the transistor. Enclosed are the many components used to make monolithic-integrated circuits, multichip circuits, and hybrid-integrated circuits.

Component preparation. Most component leads are gold plated during the manufacturing process to prevent their oxidation. If the leads are gold-plated, you must remove the plating from the leads with a white, pencil-style typing eraser or other specialized cleaner before you make any attempt to solder them. If the leads are not plated, use the typing eraser or a component lead cleaner to remove the oxidation.

Circuit-board preparation. Printed-circuit boards should be thoroughly cleaned and prepared for component installation. Different boards and their methods of preparation are described below:

a. Tinned lead-plated boards are the easiest to prepare. All you need to do is clean them thoroughly with a medium-bristle brush and alcohol, and then wipe them dry with a lint-free cloth or tissue. Be sure that each hole and pad is free of foreign matter.

b. Clean copper-clad unplated boards with a white pencil-style typewriter eraser. The pad is clean when the whole pad shows a bright uniform appearance. Follow this cleaning with the brush and alcohol cleaning treatment.

c. Gold-plated boards are the most difficult to prepare because the gold plating must be removed from all areas to be soldered. Remove the plating with the white, pencil-style typewriter eraser. A uniform gold-pink color all over the pad is the required condition. Again, follow this with brush and alcohol cleaning.

Component mounting. A component can be mounted on the PC board in a variety of ways. The two most common methods are flush mounting and embedded can. In the embedded-can method, you mill out the PC board to set the package into the recessed slot bottom up. This type of mounting is the most desirable because it permits the use of a heat sink.

For clinched lead termination, first insert the component on the board. Using a pair of flush-cutting pliers, cut the leads to the proper length. The minimum length is the pad radius and the maximum length is the pad diameter. Using a lead-forming tool, force the leads over in the direction of the PC board conductor run until they are flush with the board.

On special mountings where a round pad is used, the lead is not clinched. It comes straight through the board for a distance equal to the width of AWG 20 wire. Hold a piece of AWG 20 bus wire next to the lead and cut the lead flush with the wire.

After the component lead is properly formed, cut, and clinched to the board, clean the connection once again with the cleaning brush and alcohol. Do all soldering on the board with the board flat on the cleaning pad. If you must use a heat sink on a heat-sensitive component, place the board in a PC board holder.

Clean the tinned soldering iron tip by wiping it slightly with a wet sponge. It is important that the iron tip be free of old solder because old solder does not mix with new solder.

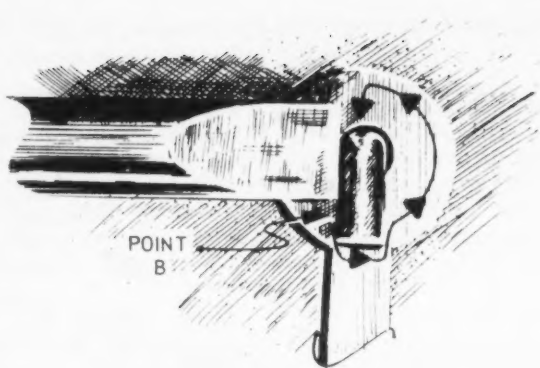
A good temperature for most joints is one that is hot enough to melt the solder readily and heat the joint without damaging the board or component. In most cases, microminiature packages are soldered into the circuit with a 17-watt iron and a variable voltage source setting of approximately 100 volts. For larger pad connections with less sensitive components, a standard 37-watt iron is desirable.

While you must keep the application of heat to a minimum when you connect micropackages to PC boards, enough heat must be transferred to the surface to ensure a reliable connection. One method of ensuring sufficient heat quickly is to use a heat bridge. A heat bridge is formed when the soldering iron tip and the component lead are bridged with a small diameter, low-melting-point solder. Place the iron tip flat against the side of the component lead and center it on the pad, as shown in figure 5-26. Form a heat bridge at point B. Move the solder down the lead (in the direction indicated in figure 5-26) to the wire end. Tin the cut end and then move around the pad back to the soldering iron. Remove the iron and solder. After the joint is cool, clean it thoroughly with a brush or tissue dipped in alcohol.

To replace a component, wick off all solder on all joints and remove the component. Prepare the PC board and install the new component, using the procedures outlined in the above paragraphs.

Exercises (044):

1. Give the procedures for preparing a copper-clad unplated board for a soldering operation.



NCS13-32

Figure 5-26. Soldering operation.

2. Describe the appearance of a gold-plated board that has been properly prepared for a soldering operation.
3. State the procedures used in the heat-bridge method of soldering.

5-8. The PACE Electronic Maintenance System

This section deals with the PACE electronic maintenance system. Many of you have probably already seen a PACE station being used in your work center. This equipment provides a maintenance section with the ability to restore electronic equipment to its original quality and reliability standards. The PACE system is comprised of a power source and a number of functional accessories that combine to perform the high-reliability soldering and repair work necessary today.

Please note that although the information contained in these objectives was extracted with permission from the PACE Manual for Electronic Maintenance System, Model PRC-350C, we strongly recommend that you read the instruction manual provided with your system before using it.

045. Identify the controls of a PACE system's power source.

Power Source. The power source is the heart of the PACE system. It provides all the following functions: air pressure, vacuum, mechanical power, an infinitely variable low level of AC and DC power, and finally, two levels of fixed and three levels of variable AC power. These capabilities can be used to do almost any electronic repair or soldering operation.

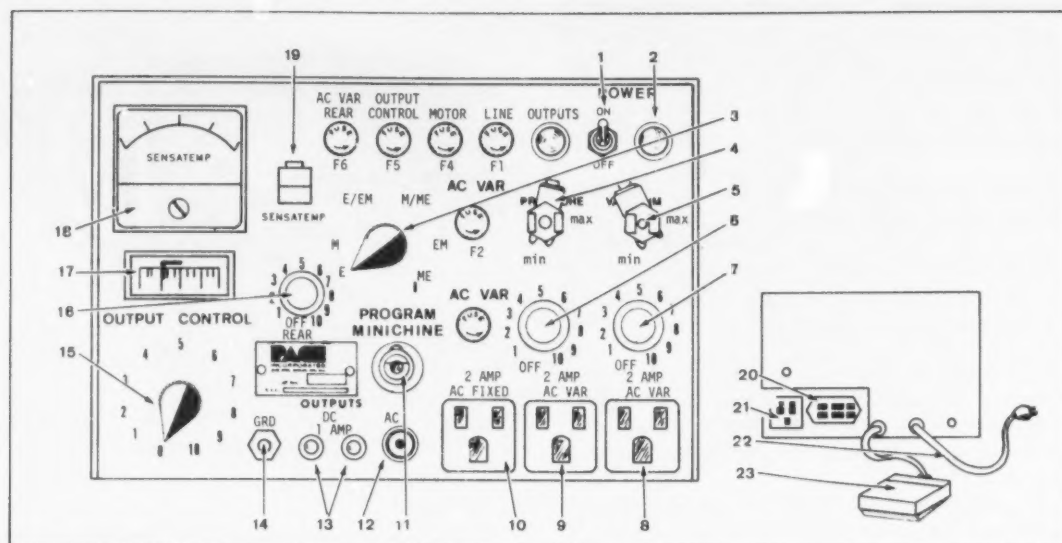


Figure 5-27. Power source.

Figure 5-27 shows many of the controls located on the power source and the following text outlines their setup and use.

a. Before applying power, all switches and control knobs should be placed in the OFF or "O" position.

Connect the power cord (22, fig. 5-27) to a properly grounded outlet.

c. Turn the main power switch (1) ON. The red main indicator (2) should be lit and the fixed AC line receptacle (10) should be hot. Also, variable AC receptacles (8, 9, and 21) can now be activated and controlled by controls (6, 7, and 16).

d. For many of the functional accessories provided with this system the mode selector (3) will provide the mechanical and/or primary electrical power needed. The two-position foot pedal (23) allows foot control over the power supplied to the accessories. The various combination of motor (M) and primary electrical power (E) provided are listed below:

Position 1.E—Foot pedal activation provides primary electrical power to both the AC and DC outlets (12 and 13). Output control (15) controls the output level of these low-power signals. The exact level of DC output can be monitored with the DC volt readout (17).

Position 2.M—Provides power to the minichine (11) and allows either pressure (4) or vacuum (5) to be activated by the foot pedal.

Position 3.E/EM—The first position of the foot pedal will provide power to the primary electrical AC and DC outputs. The second position of the foot pedal provides both primary electrical and motor outputs.

Position 4.M/ME—In this mode, the motor is activated in the first foot pedal position, and both the motor and primary electrical power outputs are again provided in the second.

Position 5.E/M—The first position of the foot pedal will activate only primary electrical power and the second will activate only the motor.

Position 6.M/E—The reverse of the previous position.

e. The ground terminal (14) should be used as required to protect a workpiece (the component being worked on) from stray current flow.

f. When the motor is activated, mechanical power is provided to the minichine (11) in one of two modes, *idle* or *quick-connect while running*. Please consult your operating manual for specific guidance on how to use these modes.

g. Pressure and vacuum flow rates are variable from minimum to maximum as shown on their controls (4 and 5). The maximum pressure and vacuum flow rates are factory set but can be reduced by loosening the ball caps on the controls.

CAUTION: Presented here and throughout this section are many precautions that should be taken. When you use the low-voltage AC or DC outputs, remember that their usage is based upon a 50-percent duty cycle; i.e., for each 5-second period power is applied, there should be a 5-second period that power is OFF. Accessories such as the tungsten or carbon-type resistive heating elements are especially susceptible to degradation if not provided this cooling-off period. Items exempt from this standard are: the miniature soldering units, thermal parting unit, and the thermal stripping unit. Except for these exempted items, no accessory using this low-voltage AC or DC output should be used for more than a 10-second continuous period. Again, please consult the operating manual for specific guidance on each accessory.

As you know, *heat* is required for all soldering and desoldering operations, but the application of too much heat will damage many of today's electronic circuits. You should use only enough heat to reach the solder's melting point. This is necessary to prevent damage to the electronic circuits. Remember many of today's bonding and coating materials have a melting point that is only slightly higher

than the melting point of solder. Precise temperature control is provided over all conductive heating elements used with the PACE system by using the SensaTemp^(TM) and its adjacent temperature readout (18 and 19, fig. 5-27).

To use this device, place the heated component against the SensaTemp and read its temperature on the scale. The specific temperature required to reach the melting point of your solder is achieved by varying the voltage applied to the component. Remember that earlier in this chapter, we discussed the solder melting point of various eutectic combinations. As a general rule, if the type of solder is not known, start at a temperature of 350°F.

Exercises (045):

1. In mode M, what functions are available from the PACE power source?
2. When should the ground terminal be used?
3. Which devices are very prone to heat damage if not given a cooling-off period?
4. How much heat should be applied to a component that is to be soldered or desoldered?

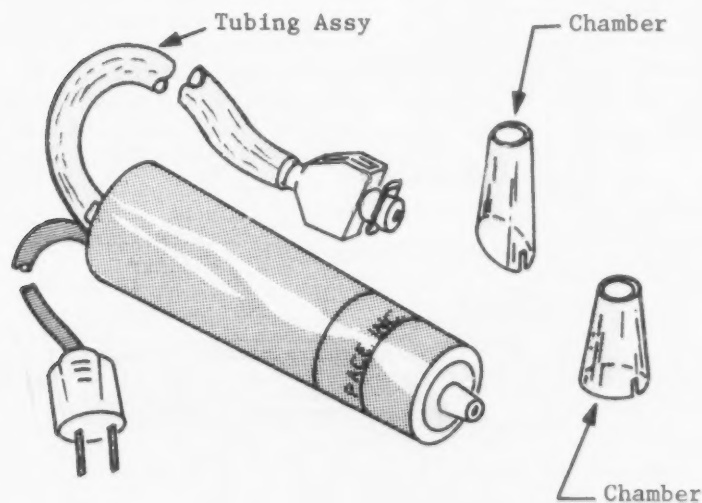
046. State the purpose and proper use of the functional accessories used with the PACE power source.

Functional Accessories. It is the functional accessories that transform the capabilities of the power source into a working output. An explanation will be provided for the function and purpose of each of the following accessories: environmental probe, SODR-X-TRACTOR unit, minichine system, thermal stripper, resistweez unit, thermopart system, lapflo system, and the conductweez device.

Environmental probe. Figure 5-28 shows the components that make up the environmental probe. This unit provides a variable hot air output that can be used for the rapid drying of localized areas, for accelerating the curing process of coating and bonding materials, and for troubleshooting.

The probe is connected to the *Fixed AC* output and the *Pressure* side of the power source. Initially you should apply power for a period of about 30 to 45 seconds. Then, with power still applied, turn on the air supply and allow the probe to stabilize for approximately 2 to 3 minutes before using.

When you use the probe for fault isolation (heating or cooling an individual component to induce breakdown) first select the proper chamber to fit over the workpiece (i.e., either the round or slightly flattened unit) and then assemble the chamber with the probe, as shown in figure 5-29. Do not try to force the chamber over the workpiece, but rather form it to fit so that it makes a seal with the surface that the workpiece is located on. When the probe is used for drying or curing, localized temperature accuracy is not critical. You may use either of the probe chambers or one of the tips furnished with the vacuum tweezer unit.



NCS18-618

Figure 5-28. Environmental probe.

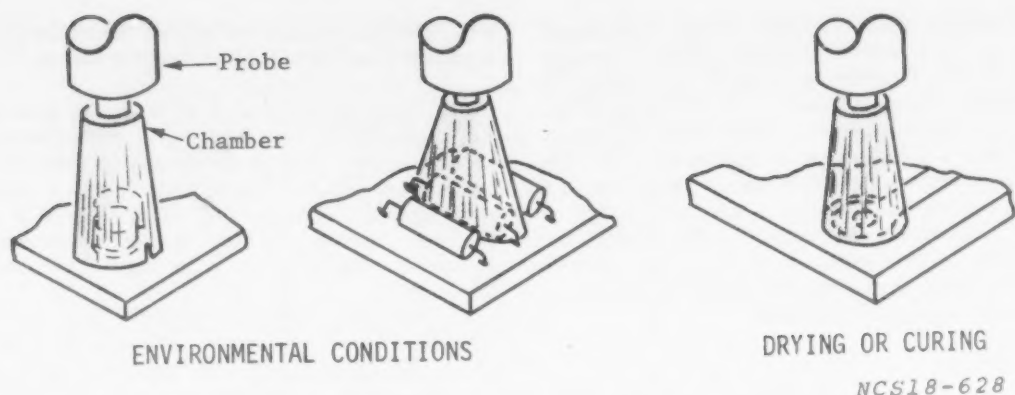


Figure 5-29. Environmental probe uses.

SODR-X-TRACTOR. The SODR-X-TRACTOR, shown in figure 5-30, functions as a vacuum cleaning device for solder removal. In operation, the heated X-TRACTOR tip quickly melts the solder. Then, with the power source in the motor mode, depressing the foot pedal generates sufficient vacuum pressure to transfer the melted solder from the circuit to safety chamber in the SODR-X-TRACTOR handle. To prevent blockage of the heater chamber, ensure that you maintain vacuum pressure for at least 2 seconds after solder extraction is done.

Items that are essential to effective use of the SODR-X-TRACTOR are proper tip selection and care and maintenance of the unit. Care and maintenance will be covered later in this section. The key factors in making proper tip selection are: match the tip to the work; ensure that the tip fits loosely over the component being soldered (this provides the necessary clearance for air and molten solder flow); ensure that the outer diameter of the tip is always smaller than the width of the pad so that the unit does not come in contact with the substrate of the circuit card; make sure that the selected tip extends approximately 5/8-inch beyond the heater body; and always use the largest tip that can be safely applied to the surface being desoldered.

The setscrew at the end of the heater units is treated with a special factory-applied lubricant and should not require additional lubrication. However, loosen this setscrew at least once during each 8 hours of operation to prevent possible seizing.

Striptweez, thermal wire stripper. The striptweez unit, shown in figure 5-31, is capable of stripping wire gauges of #12 through #30 AWG; and, with care, can be used on wire gauges to #43. Figure 5-32 illustrates the three-step procedure used to strip a coaxial cable. First, place the wire between the blades at the desired length to be stripped, then clamp the blades to the insulation. While maintaining light pressure on the insulation, depress the foot pedal to heat the blades. The blades should penetrate the insulation in approximately 2 seconds or less. As penetration occurs, slowly rotate either the wire or the stripper in a circular motion to achieve complete penetration. Do this operation as quickly as possible to prevent possible overheating and damage to the center conductor. Once complete penetration has occurred, release the foot pedal and allow the blades to cool for a moment, then remove the insulation. Now, push back the shield and repeat this procedure on the inner insulation. Finally, trim the shield to the desired length.

Minichine system. The minichineTM, shown in figure

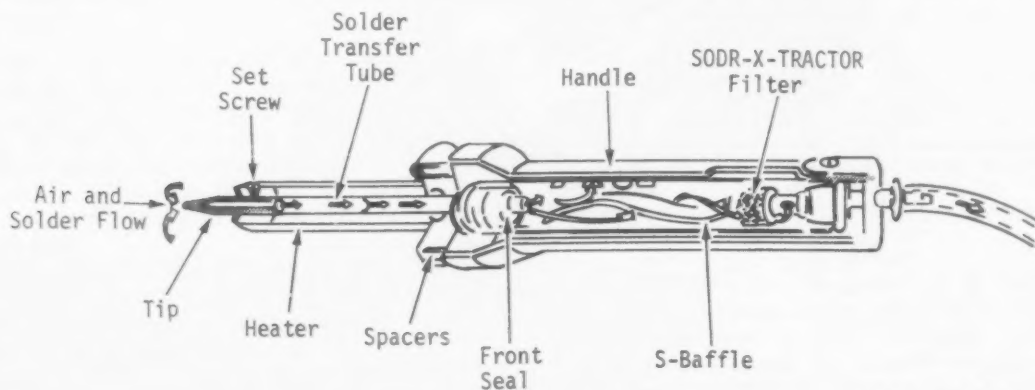


Figure 5-30. SODR-X-TRACTOR.

NCS18-620

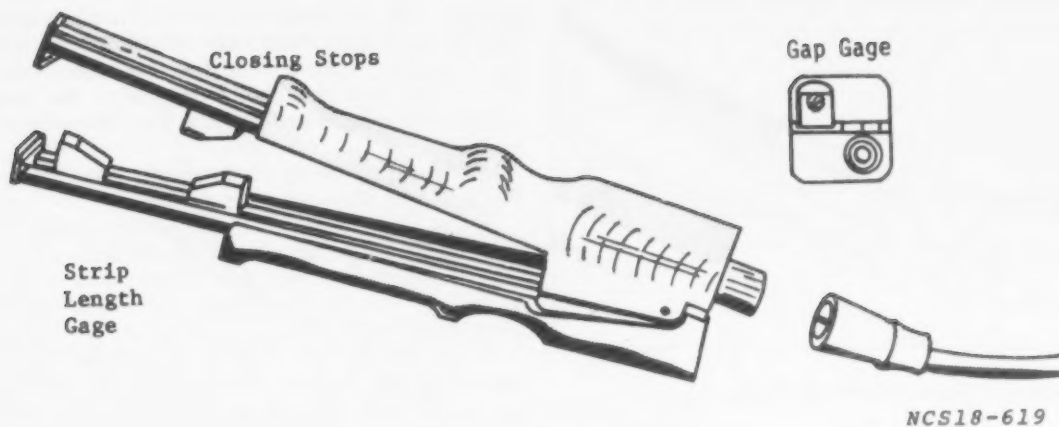


Figure 5-31. Thermal wire-strippers.

5-33, provides for a number of different machining operations to aid you in your repair work. Included in its functions are the following: abrasive removal of coatings; slitting inaccessible part leads; slitting parts, bonds, and housings; routing of coatings; removing standoffs or terminals without damaging the circuit card; and, finally, drilling small diameter holes. Please consult your operating manual for specifics on using this accessory.

Resistweez. The resistweez^(TM) resistance heating unit, shown in figure 5-34, can be used to do a broad range of heating and soldering work when it is undesirable, or not possible, to use a standard soldering iron. It provides a very localized heating surface that may be used to solder terminals, connector pins, etc. The following guidelines are provided for using this system.

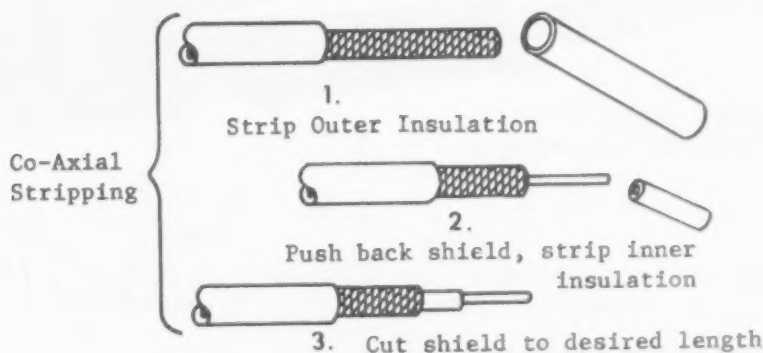
- Ensure both the tweezer tips and the workpiece are clean to provide low-contact-point resistance.
- Apply power to the unit only after the tweezer tips have been engaged to the workpiece.
- Ensure that power is off prior to disengaging the unit from the workpiece. (These first three steps will reduce the possibility of arcing.)

d. To avoid possible damage, apply power only long enough to reach the solder melting point.

You will find that using the resistweez unit will both simplify and improve many of the soldering tasks you are required to do.

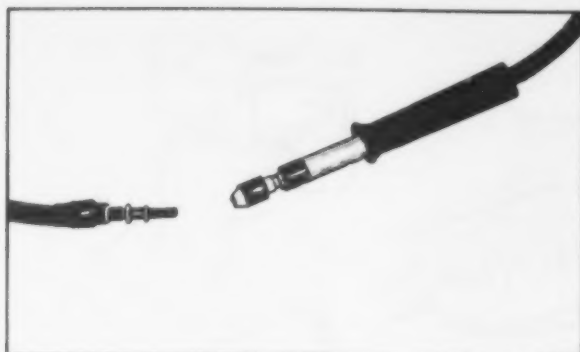
Thermopart unit. The thermopart unit provides an efficient and controllable means for thermoparting and desoldering. Figure 5-35 shows a unit that consists of a pencil-like holder and an interchangeable blade. This device can be used as a thermopart unit or a lapflo soldering unit, depending upon the type blade being used. The lapflo work will be covered later. All PACE systems come with a standard V-shaped blade that can be modified (bent 90°, etc.) when required to do almost any thermoparting or desoldering task.

Many of today's electronic circuit cards are coated with compounds that range from a simple varnish to a two-part epoxy coating of extreme hardness. The thermoparting unit can be used to remove all of these. The primary caution that should be exercised when removing any coating is setting the right temperature. As a general rule, with heat applied,



NCS18-624

Figure 5-32. Thermal stripping.



NCS18-627

Figure 5-33. Minichine (TM).

an epoxy surface will granulate and a poly-u surface will soften at the point removal is possible.

The thermopart unit may be used to do a variety of desoldering jobs and should be used whenever you are desoldering clinched leads. To unclinch a lead, heat the solder until it melts and then *lift* the lead from the pad; *do not pry*, as prying may damage the pad.

Lapflo soldering system. A large percentage of round and flat leads terminate in a lapjoint such as the one shown

in figure 5-36. Soldering a lapjoint is a two-part operation that has been made much easier with the creation of the lapflo soldering system. This procedure requires that you first tin the pad, then solder the lead to this prepared surface. Listed below are the procedures required to do this task.

a. Using a typing eraser, thoroughly clean each pad so that its surface is shiny and bright.

b. Lay solder the length of the pad; then, using the flat tip of the lapflo element, clamp the solder to the pad.

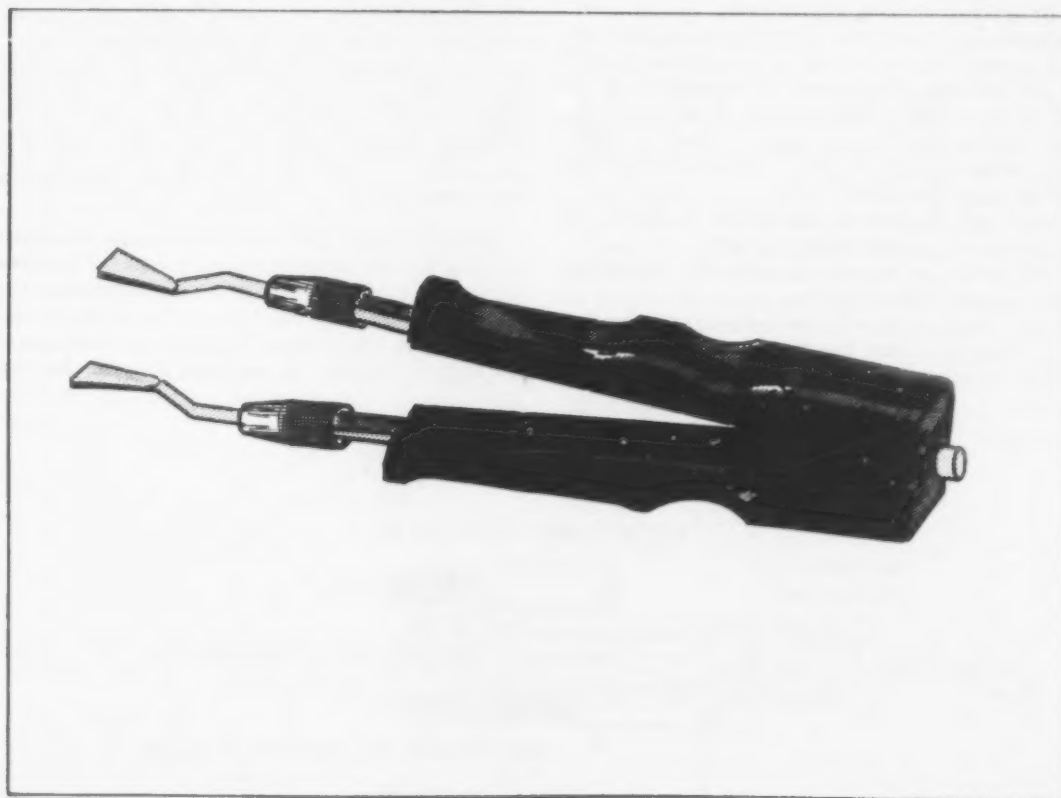
c. Energize the unit and observe that the solder completely wets the pad surface. This should be done as quickly as possible to prevent overheating.

d. If a pad requires reheating to complete the wetting process, be sure to allow the surface to *cool down* before you reapply heat. This will also help prevent damaging the pad.

e. After tinning all pads, form the leads of the component to be soldered so they make uniform contact with each pad. Failure to do this may result in a cold solder connection.

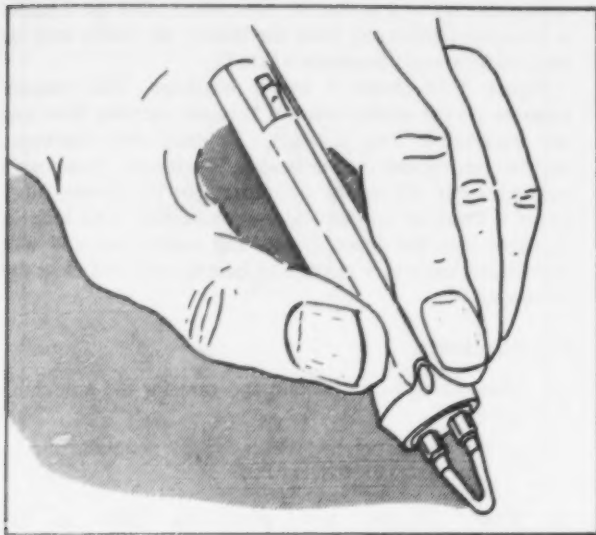
f. Make sure the component is properly *oriented* before soldering; i.e., ensure that pin N1 is attached to pad N1, etc.

Now, using the power level used to tin each pad, apply heat to the lead and observe the formation of a lapjoint.



NCS18-623

Figure 5-34. Resistweez (TM).



NCS18-621

Figure 5-35. Lapflo soldering unit.

Deenergize the unit and allow the connection to cool for a few seconds prior to removing the lapflo element.

Conductweez soldering unit. The conductweez soldering system provides heating and soldering capabilities that, until now, have been unavailable with resistance-type devices. The resistance-type (resistweez) system transmits heat by means of passing a high level of current through the workpiece. Although this method does provide high-speed localized heating, it can cause arcing due to the difference in contact resistance, or it may damage the workpiece because of its high level of current flow. The conductweez system, shown in figure 5-37, overcomes all of these deficiencies. It uses a pair of pulsed electrodes that transmit heat through the workpiece by means of conduction (just as a standard soldering iron does, but from both sides simultaneously). By using a conductive means of heat

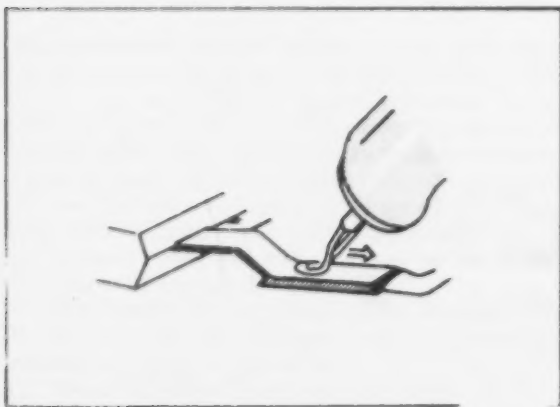
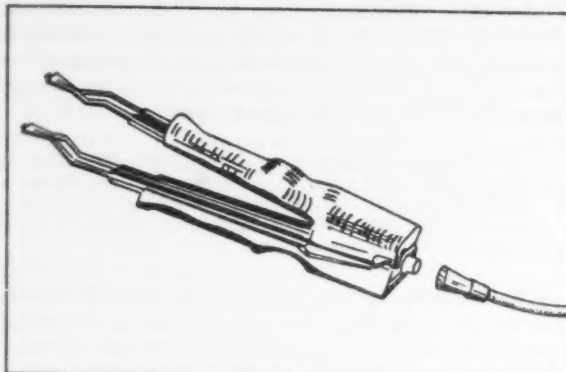


Figure 5-36. Lapflo soldering.



NCS18-622

Figure 5-37. Conductweez.

transfer, the problems of current flow and arcing are eliminated. The conductweez system should be used in all cases where the current-handling capability of the workpiece is in question. In particular, this system is well suited for cross-wire soldering and for withdrawing soldered-in clipped leads.

Exercises (046):

1. What can you do with the environmental probe?
2. Give at least three requirements for selecting the proper tip to be used with the SODR-X-TRACTOR.
3. When using the resistweez unit, why is it important to clean both the workpiece and the tweezer tip?
4. What is the most important caution that should be taken when using the thermopart unit?
5. What is the purpose and advantage of using the conductweez soldering system?

047. State the care and maintenance procedures used with the PACE station.

Care and Maintenance. Routine care and maintenance procedures for the PACE station normally consist of nothing more than placing a few drops of lightweight oil where it is needed and cleaning those elements that require it. Presented here are some of the most common procedures that you should use.

Periodic lubrication. If the setscrew on the SODR-X-TRACTOR is not the original, it should be removed and coated with an antiseizing compound at least once during each 8 hours of operation. If you are in doubt about whether the screw is original, coat it.

CAUTION: When replacing the tip of the SODR-X-TRACTOR, ensure the setscrew is tightened no more than one-fourth of a turn beyond the point that it first makes contact with the tip. Any further tightening will cause the tip to collapse and prevent proper operation.

The minichine requires that the spindle assembly be oiled at least once during each 10 hours of operation. To do this, place a few drops of lightweight oil in the hole provided. Should you notice a vibration in the shaft assembly, apply a few drops of oil to the space between the drive-shaft key and the grooved end of the assembly. Then place the unit on end so the oil is allowed to drip down into the sheath.

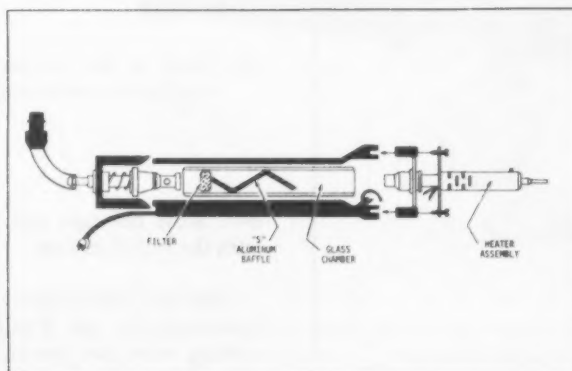
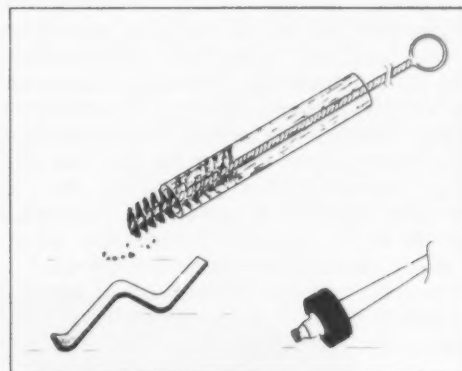
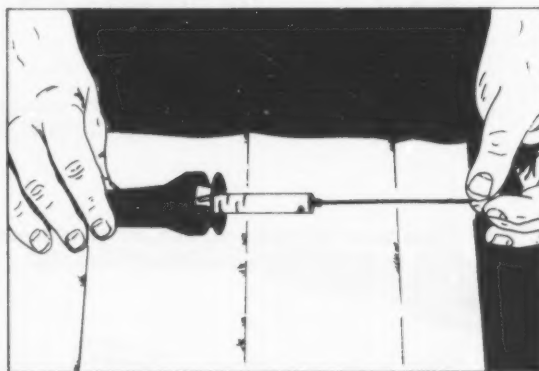
Cleaning. The SODR-X-TRACTOR should be cleaned as often as necessary to maintain full vacuum flow. The normal cleaning procedure is outlined in figure 5-38. As shown, first remove the tip and clean the heater assembly with a wire brush. Then, clean the glass chamber and the S-baffle with the wire brush; if necessary, coat them with a light coating of mineral oil to aid in the cleaning. The filter at the back of the glass chamber should be replaced as often as necessary to maintain a full vacuum flow. Finally,

reassemble the unit as shown. Also, ensure that the S-baffle is securely fitted away from the heater; the baffle may be bent, as necessary, to ensure a firm fit.

Figure 5-39 shows a heater blockage. This usually happens during solder removal because vacuum flow was not maintained long enough. To clear this blockage, remove the tip and set the heat to maximum. Now, melt approximately 18 inches of solder into the heater tube. Insert a brass or copper rod approximately 3/32 inch in diameter into the heater tube. The solder and rod will transfer the necessary amount of heat to melt and clear the blockage.

Exercises (047):

1. How should you maintain and care for the minichine unit?
2. What indicates how often the filter in the SODR-X-TRACTOR is replaced?



HCS18-630

Figure 5-38. SODR-X-TRACTOR care and maintenance.



NCS18-626

Figure 5-39. Heater tube blockage.

5-9. Fabricating Cables

As a radar repairman, you are required to fabricate cables for electronic equipment, and it is your responsibility to ensure that they are correctly made and checked. An improperly constructed cable can cause electronic failure at a critical time, and it can damage components in the equipment with which it is used. Faulty cables can even cost the lives of operator and maintenance personnel. You can see how important it is for you to know the proper procedures for constructing, inspecting, testing, and repairing cables.

The material used in cable construction must meet all the specifications outlined in the TCTO, the equipment technical manual, or the authorization for the particular installation. You can do good work by closely observing and following the directions given in these references.

048. State the key points in the procedures for fabricating, binding, or tracing a multiconductor cable.

Multiconductor Cables. Multiconductor cables have from two leads to many leads. In this type of cable, several different wire sizes may be needed, depending on the amount of current each wire must carry. The amount of insulation on any lead is determined by the potential along the lead. In most cases, high-voltage cables are fabricated at the factory. Extremely high voltages use a special high-voltage cable. You can find the exact specifications for all multiconductor cables used with a given item of equipment in the equipment's technical order.

Complete fabrication instructions should be available to you; but reviewing the following steps in constructing multiconductor cables will be useful:

- (1) Obtain the cable wire and cable connectors.
- (2) Obtain the cable tags, soldering tags, spaghetti insulation, plastic electrical tape, and lacing cord.

(3) Lay out the proper tools in your work area.

(4) Disassemble the connector and make sure that all parts are clean (fig. 5-40,A).

(5) Clean and tin the connector pins (wiring cup ends) (fig. 5-41).

(6) Place the connector insert into a vise, the wiring cup side up so that the pins are in horizontal rows. Be careful not to crack the inserts by overtightening the vise.

(7) Cut the wire to the specified length. Strip and tin about 1/4 inch of one end of each wire (fig. 5-40,C).

(8) If shielded wires are used in the cable, push the shielding back about 1 1/2 inches.

(9) Slide a 5/8-inch length of spaghetti insulation of the appropriate diameter on each wire at the stripped and tinned end (fig. 5-40,C).

(10) Solder each wire into its proper pin, beginning with the row of pins at the top and working across and down. Heat the connection pin solder cup sufficiently to melt the solder in the cup. Insert the tinned end of the wire into the cup and remove the soldering iron from the pin. Do not move the wire until the solder has set. After the connection has cooled, slide the spaghetti over the connection. Be very careful not to burn the insulators or overheat the connector insert. Otherwise, short circuits or leakage can result.

(11) Wrap the cable with five or six turns of plastic electrical tape next to the ends of the spaghetti. Taping holds the spaghetti in place over the connections. If you are using the shielded wires, bond the shielding to two or more pieces of scrap shielding, which should extend out of the cable for a few inches. These will be soldered to a grounding lug, which will be attached later to one of the screws on the cable clamp.

(12) In some instances, the shielding is not grounded but is connected to other connector pins. In such a case, prepare and insulate the wire as before; then solder the pigtail lead from the shield to the proper connector pin.

(13) Remove the cable connector insert from the vise.

(14) Reassemble the connector, tightening all of the parts except the cable clamp, which must be left loose to allow the cable covering to be inserted later (fig. 5-40,A and B).

(15) Arrange the cable wires neatly with no excessive twists or tangles. These can affect the length of the wires.

(16) Lace the cable. Ribbon-type lacing cord is preferred to round cord because it minimizes insulation damage. (Proper lacing techniques are covered later in this chapter.)

(17) Tape the untripped ends of the wire together for about the first 6 inches with a wide strip of adhesive tape.

(18) When you measure the plastic outer cable housing, allow an additional 2 inches of slack for each 10 feet of cable housing.

(19) Use tracing cloth powder to facilitate pulling the cable through the housing. Powder the cable wire—especially the taped end—and the inside of the cable housing.

(20) Tie the taped end of the cable to a metal rod. Push the rod through the plastic sheath and fasten the exposed end of the rod in a vise. Pull the housing over the bundle of wires.

(21) Cut a small hole in the cable housing about 2 inches from the assembled connector end and pull the shielding ground wires through.

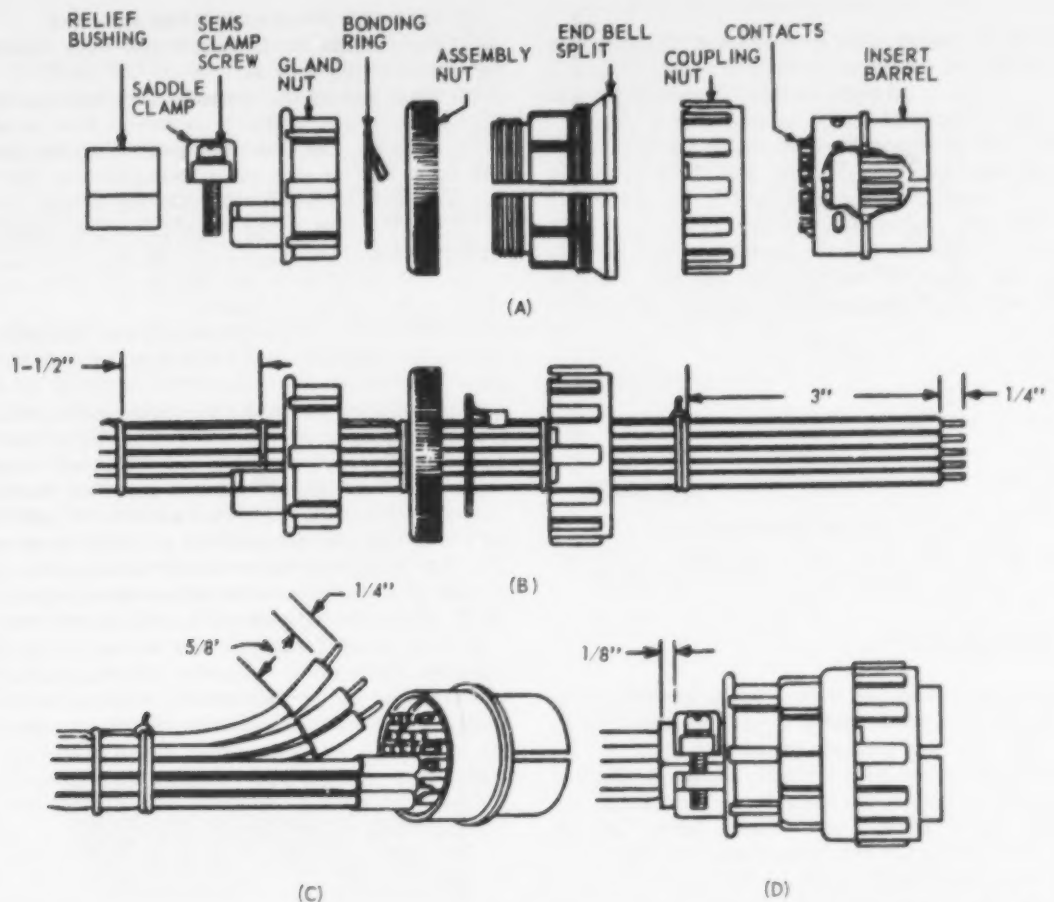


Figure 5-40. Multiconductor cable.

NCS13-38

(22) Work the housing under the cable clamp on the connectors as far as possible. Tighten the cable clamp to hold the plastic housing in place.

(23) Solder the ground shielding wires to the soldering lug and fasten the lug to the connector cable clamp.

(24) Now pull the cable housing far enough onto the cable to allow you to work with the taped end.

(25) Mount another connector in the same way on the other end of the cable, following the above step-by-step instructions.

(26) Use an ohmmeter and check continuity to be sure that you locate the proper wire to solder to each connector pin. In assembling some cables, the wires do not connect letter to letter. For instance, pin A may be connected to pin D. In such cases, refer to the wiring diagram in the technical manual for each wire connection. If the cable is nonreversible, the ends must be labeled at the time of construction, since a reversal of the cable will cause improper operation and possibly damage the equipment.

(27) After the solder connections cool, slide the spaghetti over each connection to the connector insert, as before.

(28) Remove the cable connector insert from the vise. Reassemble the connector, leaving the cable clamp loose.

(29) Cut a small hole in the plastic cable housing, as before, and pull the shielding ground wires through.

(30) Push the plastic sheath into the cable clamp as far as possible and tighten the clamp to hold the housing in place.

(31) Solder the shielding ground wire to a solder lug and fasten it to the cable clamp.

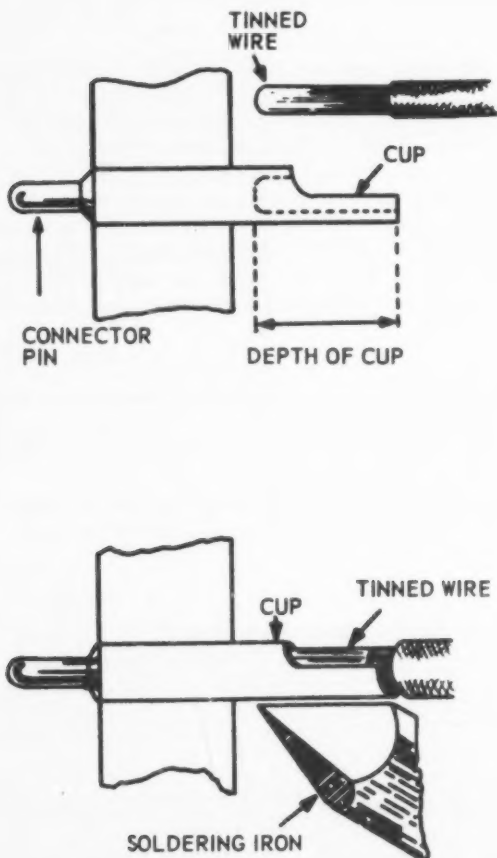
(32) Attach the cable identification tag, bearing the proper cable number, to each end of the cable near the conductor.

(33) Check the cable thoroughly for shorts, leakage, and continuity. If possible, connect the equipment on the test bench, using the new cable. Operate the equipment to be sure that the cable is serviceable.

Cabling and Harnessing. Proper cabling and harnessing

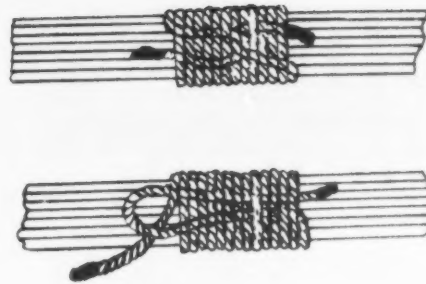
are quite important in electronic equipment. Excessive stress on a cable or harness can break a connection, leading to equipment malfunction and perhaps to a loss of life. To decrease the possibility of undue stress on the cables, they are bound or laced together. The binding or lacing should be sufficiently tight to prevent slippage but should not cut or deform the conductor insulation. Refer to your command directives for specific guidance on binding, lacing, and breakouts.

Binding. Binding, or spot tying, is making a series of individually bound wraps at equidistant points along the cable. Cut the cord about 2 inches longer than the length needed to make twelve turns around the harness. Form one end of the cord into a 1-inch loop and place it flat on the harness, parallel to the wiring. Wind twelve turns tightly over this loop and, at the last turn, push the cord end through the loop that extends from under the wrap. Pull the end of the cord that was looped until the loop is under the wrap but only far enough for the two loops to intersect near the center of the wrap (fig. 5-42). Normally, the loose cord ends will need trimming after the completion of this spot tie.



NCS13-39 A

Figure 5-41. Soldering leads to multiconductor.



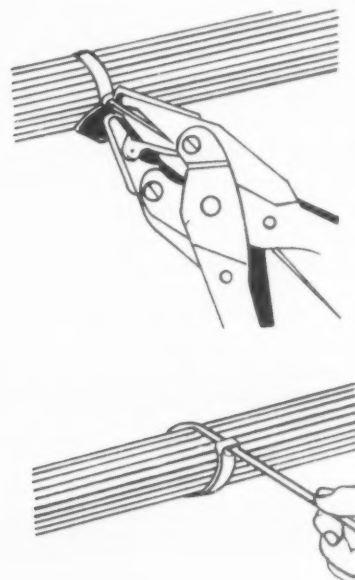
NCS13-40

Figure 5-42. Cable lace, spot tie.

Another method of spot tying is done with a nylon strap (fig. 5-43). Slip the nylon tie around the conductors, thread it through the tie eye, and draw it up tight.

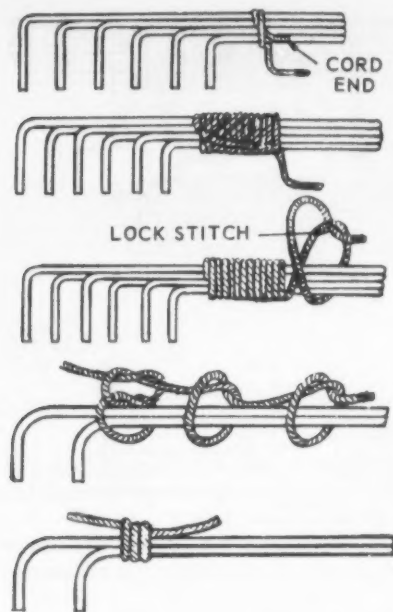
Lacing. Cables should be laced with a ribbon-type lacing cord (in preference to round cord) to minimize insulation damage.

To start lacing, lay one end of the lacing cord alongside the principal cable, pointing in the direction of the proposed harness. Secure the end of the cord by winding approximately four turns of the cord over it and continue wrapping until you have wound a total of twelve turns around the principal cable (fig. 5-44). Secure this wrap with a lockstitch made by forming a loop, passing the cord over and then through the loop, and finally, pulling the cord tight (fig. 5-44). To form secure stitches along the cable assembly, use either single or double lockstitches.



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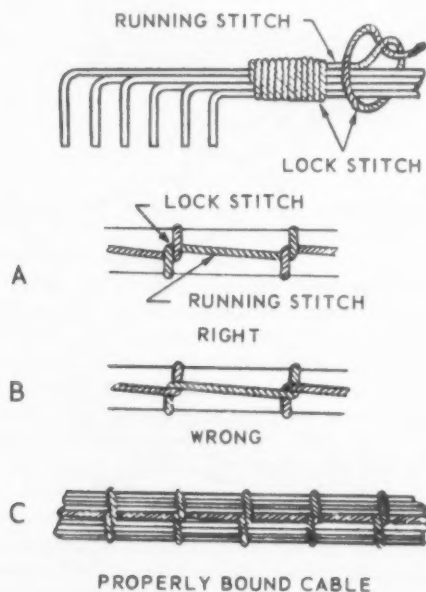
Figure 5-43. Nylon strapping, spot tie.



NCS13-41

Figure 5-44. Cable lace start.

You form the single lockstitch by lacing the cord over the loop (fig. 5-45,A). Never lace the cord under the loop (fig. 5-45,B) because it would loosen. Lacing over the loop locks the cord tight. As the lacing advances, reform the wire to ensure a neat and firmly bound cable (fig. 5-45,C).



NCS13-42

Figure 5-45. Single lockstitch.

The double lockstitch is formed in the following way:

(1) Take the lacing cord coming from the starting point and loop it over the harness. Bring it around behind the harness and insert it through the loop, as shown in figure 5-46,A.

(2) Tighten the knot, leaving a loop between the starting point and the knot, as shown in figure 5-46,B.

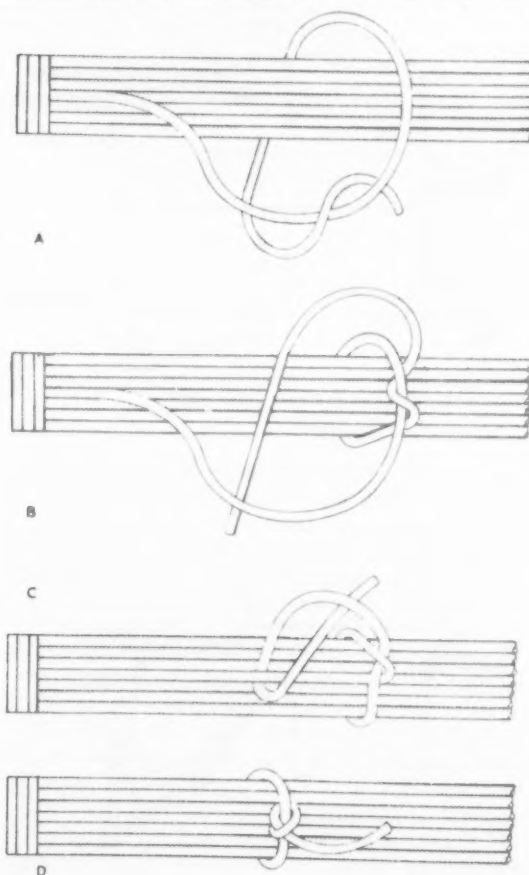
(3) Insert the end of the lacing cord through the loop, leaving a loop through which the end of the cord is again inserted (fig. 5-46,B and C).

(4) Tighten the entire stitch, as shown in figure 5-46,C and D.

(5) Continue lacing, using the same method, until the job is completed.

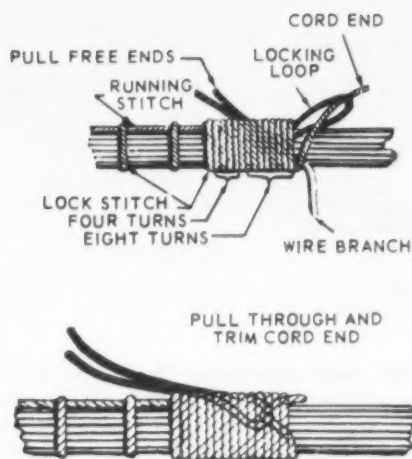
All lacing should follow the top of the harness, and, when possible, all knots or other irregularities should be hidden from view when the cable is installed.

Figure 5-47 illustrates the procedure for terminating the cable lacing. Wrap four turns of cord next to the last lockstitch and then form a separate piece of cord into a 2-inch loop and lay it alongside the cable. Wrap eight turns of lacing about the loop and draw the end of the lacing cord through the loop. Pull both ends of the loop carefully to draw the cord end underneath and out of the wrap. Pull the



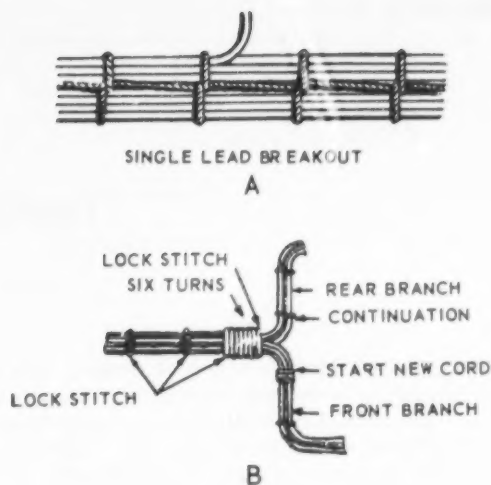
NCS13-43

Figure 5-46. Double lockstitch.



NCS13-44

Figure 5-47. Cable lace termination.



NCS13-45

Figure 5-48. Cable branching.

cord end tight, locking the wrap, and then cut the ends to approximately one-fourth inch.

Breakouts. Branches and subbranches, including single leads, are usually referred to as breakouts. A single-lead breakout should be preceded by a lockstitch (fig. 5-48,A) without any variation in the distance between stitches. Any breakout of two or more wires should be laced. When a group of wires is branched from a cable (fig. 5-48,B), wrap a lockstitch and then six turns firmly about the main cable; then make another lockstitch adjustment to these turns.

Exercises (048):

1. What determines the size of wire to be used in a cable?
2. Describe the proper procedure for placing a connector insert into a vise.
3. What length of spaghetti insulation should you use when fabricating cables?
4. What length of outer cable housing should you use for a cable that is 20 feet long?
5. Describe the steps in binding a cable with lacing cord.
6. Why is ribbon-type lacing cord preferred when binding a cable?
7. Why must you lace the cord over the loop instead of under the loop in the single-lockstitch method?

Test Equipment

WHEN TEST EQUIPMENT is in good working order and is used properly, it is the most important maintenance tool you have. However, if your test set is in poor condition or you lack a knowledge of its operation and capabilities, it can be one of your worst enemies for maintenance. In this chapter, we will try to expose you to test equipment in general (divided into families such as multimeters, power meters, etc.) and then discuss some of the specific pieces more commonly used in this career field.

6-1. Test Equipment in General

Before we get down to specific items, it is best to have a general overall understanding of the subject. In this career field you will be called upon to use test equipment to perform maintenance or operations-related duties. To prepare you for those tasks, you must have some knowledge of what each type of test equipment will do and what principles relate to each category. This first section will cover several types of test equipment and the principles involved with each.

049. Identify the use or function of a multimeter in given maintenance situations.

Multimeters. Multimeters are probably the most commonly used piece of test equipment we have because of their ease of operation and multiple uses. Multimeters are just what the name implies, meters with multiple uses. As a general rule, they'll measure varying levels of AC or DC voltages and if equipped, varying levels of resistances. These type measurements will be a large percentage of the test equipment related work you'll do. Basically, there are two styles or types of multimeters in use today. One is the older style, the analog or mechanical type, that is very sturdy. The other style is the newer digital type which is the more detailed of the two. Digital multimeters, in most cases, have a wider scaling range which allows the more minute measurements to be read accurately. The older mechanical meters rely upon meter movements to provide the measurement readout. The digital multimeters provide the measurement in digital readouts that can be scaled down into tenths, hundreds, or more. Both are being used throughout the career field for performance checks, alignments, and troubleshooting. Let's first look at some basic meter movements and some of the possible measurements that these multimeters will perform.

Mechanical meter movements. In order to understand the need for selecting the proper meter range and function, start by examining the basic meter. This movement consists of a movable coil in a magnetic field as shown in figure 6-1. When a current flows through the movable coil, it sets up a magnetic field around the coil. If the current is in the direction shown, the upper end of the coil becomes a north pole and is attracted by the south pole of the permanent magnet. This causes the meter pointer to move to the right in direct proportion to the amount of current flowing through the coil. Suppose the current needed to move the pointer to full scale in the meter movement is 50 microamperes, and the resistance of the coil is 1,700 ohms. Using Ohm's law, note it takes only 0.085 volt to produce full-scale deflection: $E = I \times R = 0.000050 \times 1,700 = 0.085$ volt.

In order to extend the range of the meter, resistor R1 is inserted in series with the coil. Then most of the voltage is dropped across R1 and the remainder across the coil. In other words, if the value of R1 were such that it dropped 99.915 volts and the coil dropped 0.085 volt, a voltage of 100 volts would produce full-scale deflection.

From this explanation, you can see that changing the value of R1 determines the voltage needed to produce full-scale deflection. This principle is used to change the range of the meter. The preceding discussion has been oversimplified, but we will note the principles involved in our next segment on voltage measurement in which various range positions are selected for different values of voltage to be measured.

If you look through a technical order on any radar, you will find that many of the checks contain steps like the following: "Check for + 150 VDC at TP3003" or "Adjust potentiometer R2 until you obtain 2.6 VDC at TP2." Since you normally use a multimeter to perform such checks, let's review the voltage function of the meter.

DC voltage measurement. Since our equipment uses both AC and DC voltages, we'll need to cover how a multimeter measures each.

The multimeter has a range switch, which allows you to select DC voltages of 0.5, 2.5, 10, 50, 250, 500, and 1,000 volts. Further, on some meters, the DC voltage may be checked at a sensitivity of either 1,000-ohms/volt or 20,000-ohms/volt, selected by a function switch on the panel of the instrument. Figure 6-2 illustrates and identifies the simplified circuits for both sensitivities. Notice that, when you select the 1,000-ohms/volt sensitivity, an

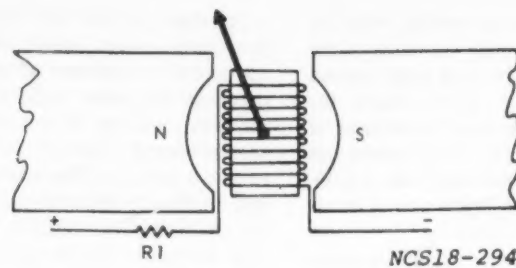
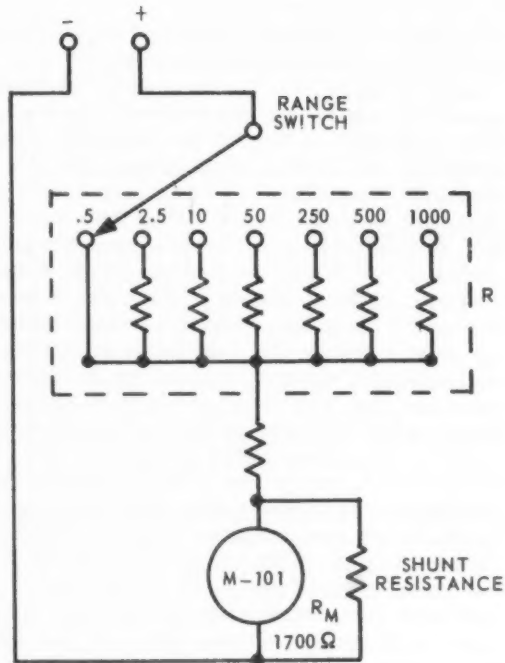


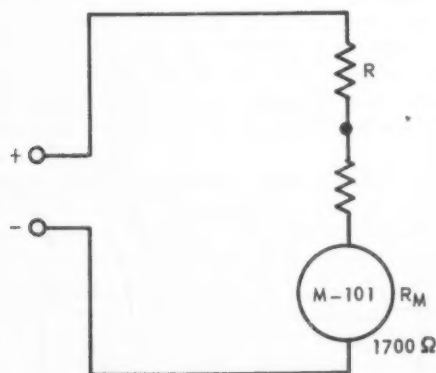
Figure 6-1. Basic meter movement.



RANGE SETTING	VALUE OF R
.5	0
2.5	2000
10	9500
50	49,500
250	249,500
500	499,000
1000	999,500

1000 OHMS/VOLT

A.



RANGE SETTING	VALUE OF R
.5	0
2.5	40,000
10	190,000
50	990,000
250	4,990,000
500	
1000	19,990,000

20,000 OHMS/VOLT

B.

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Figure 6-2. DC voltage measurement circuits.

additional shunt resistance is inserted in parallel with the meter movement, providing a bypass path for some of the current. This arrangement increases the total input current required for full-scale deflection to 1mA. Since the instrument's operation is primarily the same regardless of whether the 20,000-ohms/volt or the 1,000-ohms/volt function is selected, we will discuss only the 1,000-ohms/volt operation. If you know the operation of either function, you can easily understand the other.

With the function switch set at the DCV-1K Ω /V position and the range switch at any position, simplified circuit in figure 6-2,A, shows the basic circuit configuration used to check DC voltages. Note in the diagram that the range settings are obtained by the selection of various sized resistors. For example, when the range switch is in range 50, the value of R is such that 50 volts applied across the meter provides full-scale deflection; if the range switch is changed to position 10, then the value of R is such that 10 volts applied across the meter causes full-scale deflection, etc. (The resistance R, illustrated in fig. 6-2, is the same as the resistance identified as R1 in fig. 6-1.)

The circuit illustrated in figure 6-2,B is, for all practical purposes, identical to that of figure 6-2,A, with the exception of the resistance values used. For instance, if the function switch is set at DCV-20K Ω /V and the range switch is at any position, the circuit reduces to the simplified diagram illustrated in figure 6-2,B. Again, the value of R depends upon the position of the range switch, which is shown in the accompanying table. The total resistance, including the 1,700-ohm meter resistance, provides a 20,000-ohms-per-volt sensitivity for all ranges selected.

While we are talking briefly about DC voltage measurements, let's look at two simple things that can (and too often do) cause damage to the meter movement. Refer to figure 6-1 and note what will happen if the meter leads are connected backward in the circuit. The meter needle deflects in the opposite direction and is damaged because it is driven into the stop.

Another feature of DC voltage measurement that frequently causes meter damage is when the meter is connected to a source of voltage greater than that which produces full-scale deflection. The current through the movable coil, as shown in figure 6-1, exceeds the 50 microamperes, which the coil is designed for, and the meter needle is forced off the scale. In addition to the precautions just discussed, observe the following precautions when you are measuring DC voltage:

- Keep your hands on the insulated portion of the meter probe.
- Make sure you have the proper conditions to make the desired measurement.

Reread that last statement, "Make sure you have the proper conditions to make the desired measurement."

Refer to figure 6-3. For the purpose of illustration, assume you want to check the voltage at point A to ground. This +28 VDC is needed for energizing relay K1, completing the circuit to the indicator light. The initial conditions for supplying +28 volts at point A are: switch S1 closed and switch S2 pressed. When these conditions are met, there should be +28 VDC from point A to ground. A reading of 28 VDC indicates a normal circuit. A reading of 0 volts on the meter indicates a malfunction in the circuit. However, if one of the switches (S1 or S2) is inadvertently left open, a reading of 0 volts is not an indication of a malfunction but is normal. You can see the importance of being sure that "the proper circuit-under-test conditions have been met" before assuming a malfunction exists.

Before we close our discussion of DC voltage measurements, there is one other precautionary measure you should always observe when using a multimeter. This simple but important precaution relates to measuring high-value DC voltages. When you are measuring high voltages, you should turn off the power in the circuit, set the multimeter to the proper range and function, connect the meter in the circuit, turn the power on, and make the measurement. After you have made the measurement, turn

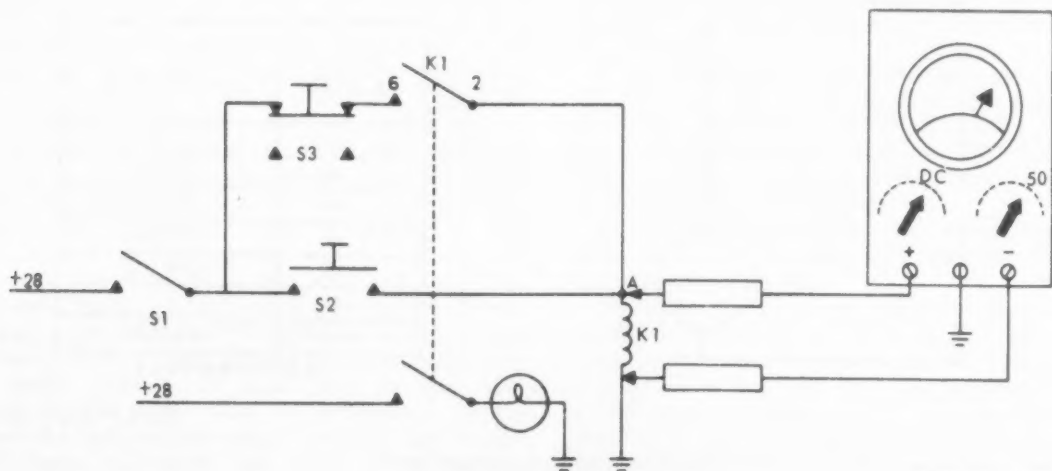
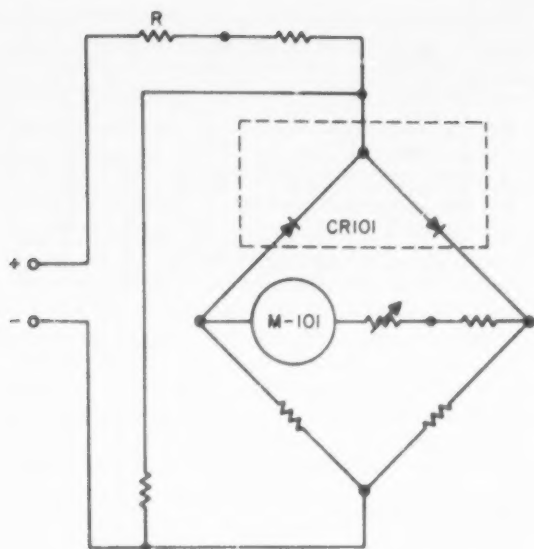


Figure 6-3. DC voltage measurement.

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RANGE SETTING	VALUE OF R
.5	0
2.5	2000
10	9500
50	49,500
250	249,500
500	499,500
1000	999,500

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Figure 6-4. AC voltage measurement circuit.

the power off and disconnect the meter. This action prevents any arcing while you are connecting or disconnecting the meter, prevents your being shocked accidentally, and prevents the equipment from being damaged while you are connecting the meter to a "hot" circuit.

AC voltage measurement. The procedures for measuring AC voltages are very similar to the DC voltage measurement procedures just discussed. Again the needed controls on the front panel of the multimeter are the function and range switches.

With the function switch set at ACV and the range switch at any position, the circuit is reduced to the basic circuit illustrated in figure 6-4 with the values of R as shown in the accompanying table. The ACV ranges are designed for a sensitivity of 1,000 ohms/volts only. The two rectifier sections of CR 101 rectify the alternate half-cycles of the incoming AC voltage, and the resulting pulsating DC is read on the meter. The variable resistor in series with the meter movement is set at the factory and is not an external operator adjustment.

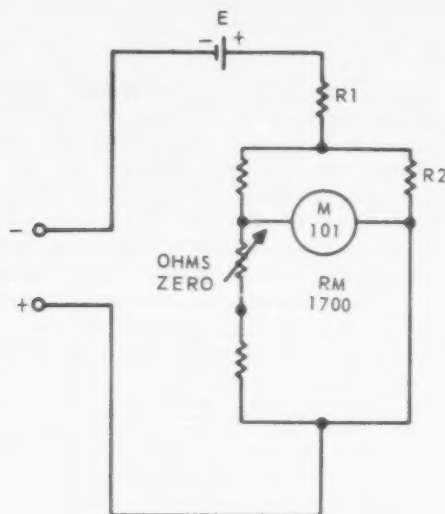
The same basic precautions apply to AC voltage measurement as to DC measurement, except it is not necessary to observe polarities. One additional precaution that should be observed, however, is not related to safety, but to the proper use of the meter in AC voltage measurement. The AC voltmeter section of most meters is designed to handle frequencies only up to approximately 1,000 Hz. Above this frequency, the voltage readings are subject to inaccuracies due to inductive reactance.

Resistance measurement. The multimeter can measure resistance as well as voltage. Although it uses the same basic meter movement shown in figure 6-1, the circuitry is quite different. The circuit contains a battery in series with

the meter, as shown in figure 6-5, to provide current for the movable coil. The ohms zero control is a variable resistor that lets you zero the meter for considerable drops in battery voltage. When the meter leads are shorted together, the variable resistor is adjusted to produce a full-scale reading on the meter. The full-scale reading indicates zero as a preliminary step in resistance measurement and you should perform it thereafter each time you select a different meter range.

If you insert a 50-ohm resistor between the leads, the current in the circuit is reduced and the meter no longer reads full scale. In other words, the size of the resistor inserted between the leads determines the current through the meter and the amount of pointer deflection. The scale is nonlinear and is calibrated to read directly in ohms. With the range switch, you can select ranges of x1, x10, x100, x1,000, or x10,000. For example, a direct reading of 67 on the scale with the range switch set at x100 means that the circuit has a resistance of 67×100 , or 6,700 ohms.

Look at figure 6-6 and see what else you should remember about the measurement of resistance with a multimeter. This figure shows a portion of the synchronizing circuit located in a typical radar modulator. Notice that the ohmmeter is connected across R630. Should you expect to get a reading of 100 on the meter? No, you should not! If you analyze figure 6-6 more closely, you will see that the current from the meter has two paths to follow. One path is from point A to point B through R630. The other path is from point A to terminal 7 or T603, through the transformer winding to terminal 8, and back to point B. Therefore, the current from the meter is flowing through two parallel paths, and the resistance measured by the meter is the total resistance of the parallel circuit instead of just the resistance of R630. To prevent this situation from



RANGE SETTING	VALUE OF R1 (Ω)	VALUE OF R2 (Ω)	E (VOLTS)
X1	.54	23.75	1.34
X10	17.5	234.8	1.34
X100	175	2583	1.34
X1000	1750	OPEN	1.34
X10,000	226750	OPEN	13.4

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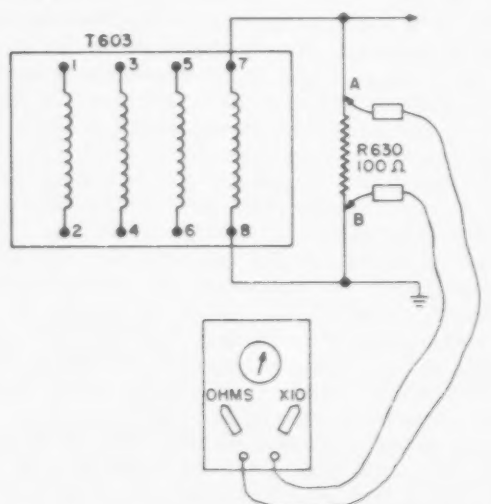
Figure 6-5. Resistance measurement circuit.

occurring, you must disconnect one end of R630 and then measure its resistance. In this way, you can measure its true resistive value. Remember, to get an accurate reading when you measure a specific resistance, you must eliminate any parallel paths. Also, never attempt to measure a resistance value with voltage still applied to the circuit.

Another point of procedure to remember when you are measuring resistance with an ohmmeter is illustrated in figure 6-7. This diagram illustrates part of a typical voltage regulator circuit. You want to measure the resistance of potentiometer R1. Of course, you have turned off the power in the circuit and eliminated parallel paths by disconnecting leads X and Y. Now, all you have to do is measure the

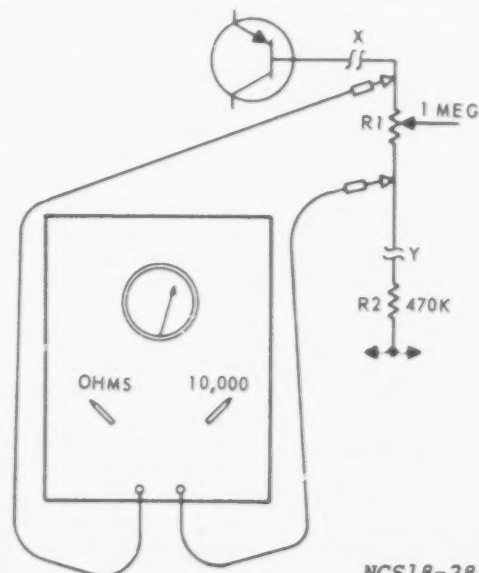
resistance of R1. But the terminals of R1 are hard to reach, so you place your fingers on the metal tips of the meter leads in order to hold the leads on the potentiometer terminals. Wait a minute though, you have overlooked one little detail—you have placed yourself in parallel with R1. You will probably get a resistance reading of 150,000 to 200,000 ohms, which is the sum of a parallel circuit made up of you and R1. This produces an erroneous meter reading, which could probably lead you down the wrong trail in troubleshooting a circuit of this type. This, in turn, can waste time and unnecessary replacement of components or parts.

DC current measurement. The remaining major



NCS18-297 A

Figure 6-6. Resistance measurement (proper circuit).



NCS18-28 A

Figure 6-7. Ohmmeter connections.

capability of the multimeter is, of course, the DC current measurement function. Direct current up to 1 ampere can be measured with most meters. To do this, set the function switch to the DCmA (milliampere) position and set the range switch at one of its positions. Let's review the basic principles and procedures involved in DC measurement.

Refer to figure 6-1, the basic meter movement, again. As we said earlier, the amount of current through the movable coil determines the amount of meter deflection. In the case we are using, the current through the coil needed to produce full-scale deflection is 50 microamperes. What would happen if you put 100 microamperes through the coil? You would damage or burn out the coil. This situation is prevented by placing a resistance in parallel with the coil. The value of resistance is such that it allows only 50 microamperes through the coil, provided that the range switch is set so that the total current in the circuit is the same as or is less than the range at which the meter is set. For example, when the range switch is set at 50 and a current of 50mA is measured, 49.95 mA flows through the resistor and 50 microamperes flows through the coil. This produces a full-scale deflection for that range switch setting and reads 50 mA on the scale. In the actual circuit, different values of shunt resistors are used for each setting of the range switch.

Here, as with voltage measurement, be extremely careful to make sure that a range setting of sufficient amplitude is obtained so that the meter needle will not be "pegged" when you are measuring DC. Remember, if the needle does not deflect far enough to get an accurate reading, the range setting can always be decreased to a point where adequate deflection of the meter needle provides a fairly accurate reading.

One other precaution that you must take when measuring DC is to make sure that the meter is properly connected into the circuit. For example, what would happen if you tried to measure this current with the meter connected as shown in figure 6-3? You would burn out the meter because the current would be extremely high. When you measure direct current, you must break the circuit and place the meter in series. In figure 6-3, you could leave switch S2 open and connect the meter across the terminals of S2. With switch S1 closed, you would read the current through K1. Remember, when you are measuring current, the meter must be connected in series.

Digital multimeters. We saved this area for last because of the similarities involved between a mechanical or analog meter versus a digital. Both types, in most cases, can measure DC and AC voltages or resistances. The need for digital multimeters arose from the use of solid-state circuitry. The older meter movement styled multimeters caused "a load" to be put on the circuits being measured and this resulted in somewhat less than totally accurate readings. Older electronic equipment that required larger voltages and currents wasn't really affected by this loading effect. As the newer equipment came to be, using transistors and other such circuitries, the effects of loading became more apparent. The transistors and the more modern solid-state circuits work at lower voltages and lower current levels. The result of using multimeters with mechanical meter movement was that the solid-state

circuits would become "loaded" or unable to operate normally when these type meters were in place. What we needed was a meter capable of "reading" the measured values without loading the circuit down. Digital multimeters follow the same principles that were discussed earlier with some variations. Digital multimeters, when used as voltmeters, basically use a counter device to produce a readout. The digital voltmeter knows what its counter is set at before any voltage is applied (usually zero). Once an unknown voltage is applied, the voltmeter has an internal device that will compare the voltmeter's count versus the unknown. If the voltmeter's count isn't large enough, the comparing device will tell the counter to count up. If the voltmeter's count is too high, the comparing or detecting device will tell the voltmeter counter to decrease its count. This goes on until the detecting device senses that the voltmeter's counter is equal to the unknown value. At this point the counting stops and the readout that's also being taken off the counter will reflect the value of the applied, formerly unknown, value. This whole process takes place in only a split second of time and has almost no effect on the circuit being monitored or measured. The accuracy of digital voltmeters is almost unlimited. Many of today's circuits require very precise tolerances, some to the second, third, or fourth place to the right of a decimal place. (Example: 1 volt, plus or minus .005 volts). Most mechanical multimeters do good to read down to a volt! Some of today's microelectronic circuits work in the 5 volt range or less and are even subject to being damaged by as much as a .25 volt surge.

Most good digital multimeters will have a selection of controls on their front that allow you to select varying scale levels, AC versus DC versus resistance measurements (ohms), etc. The functions are similar to the ones discussed earlier for mechanical multimeters but the internal processing has changed. The style digital multimeter being used will determine what functions are available and your local training will acquaint you with those that you'll be using.

As you've seen, multimeters are very versatile. Everyone always wants the newest, nicest equipment available but the equipment you may be assigned to may only need an older mechanical meter movement styled multimeter. A digital multimeter might be nice but you're going to have to use whichever multimeter that's available. Hopefully, through this section, you've gotten some idea of what a multimeter can do, the different types, and an idea of how they work.

Exercises (049):

1. If you had to use a multimeter to measure the size of a resistor that was still attached to its parent unit, what would you do first?
2. When measuring AC, what frequency levels can most multimeters handle?

3. When measuring values in/on, solid-state circuits, why should digital multimeters be used?
4. If you had to measure the output of a circuit that has a tolerance of .05 volts, what type multimeter would best be used?
5. If you were using a mechanical multimeter to measure a DC voltage and reversed the leads, what would happen to the meter?

050. Identify selected principles and functions involved with oscilloscopes.

Oscilloscopes. The continuing development of complex electronic devices demands that test equipment used to maintain these devices be more sophisticated. Oscilloscopes are important instruments in the maintenance of complex electronic devices; consequently, outstanding progress in the increased reliability and performance of oscilloscopes has been made.

Oscilloscopes are not only used for basic testing or monitoring, but they can also be used in the form of spectrum analyzers, semiconductor curve trackers, or they can furnish 3-D displays. An oscilloscope may be composed of nothing more than a power supply, cathode-ray tube (CRT), and X and Y amplifiers. On the reverse side, they can be complex enough to provide a method to monitor or observe bandwidths up to 150 MHz, 28-picoseconds rise time, range seeking digital readout, and numerous other types of displays.

The cathode-ray tube that an oscilloscope uses to present the observed signal is one of the major items controlling the performance of an oscilloscope. The tube's persistence, brightness of trace, deflection sensitivity to some extent, and bandwidth determine the limits of an oscilloscope. High performance is available in exceptionally small tubes. Some newer model CRTs are now being made with a fiber optics face.

As mentioned earlier, an oscilloscope is basically made up of a power supply, the cathode-ray tube, and the X and Y amplifiers. The power supply provides the operating voltages for the internal parts of the scope. The cathode-ray tube will have a beam being fed from its rear toward its face (the part you observe). As the beam is "shot" or sent toward the face, it can be moved by the use of the X and Y amplifiers' circuits. Think of these amplifiers one at a time to start with. The X amplifier, and its associated circuitry, will move the electron beam from left to right or vice versa. The Y amplifier circuitry moves the beam up or down. By combining the two motions, all different types of designs can be developed. Internal circuits can cause the beam to become more intense in given areas on the CRT's face.

These circuits can be acceleration grids in the CRT itself and can be controlled by external controls. By controlling the beam's speed and deflection, almost any waveshape, voltage level, or signal can be observed. The makeup of the oscilloscope will determine the limits of what it will do. The front controls allow you to spread a signal out or shrink it. You can also amplify its size (height) or reduce it. Most modern oscilloscopes will allow at least two signals to be monitored and varied at the same time. This dual-channel concept is especially useful for comparisons.

As you can see, oscilloscopes are extremely versatile. With the increased use of solid-state circuitries and the improved CRTs, oscilloscopes have become very reliable and require much less calibration. This last fact is one of the greatest advantages because if the oscilloscope is in the calibration lab, it's of no use to you. Later in this chapter we'll discuss some particular oscilloscopes common to this career field and we'll expand on some of the areas introduced here.

Exercises (050):

1. What are the basic components of any oscilloscope?
2. Which amplifier channel causes a displayed image to increase in size vertically?
3. Why are the new solid-state oscilloscopes better?

051. Identify functions of a typical spectrum analyzer.

Spectrum Analyzers. A device with wide capabilities for RF measurements is the spectrum analyzer. The functional design of the analyzers is very similar to that of a radar receiver but with a very narrow bandwidth. A cathode-ray tube (CRT), which is integral to the analyzer, is used as the display medium. It was originally designed for analyzing the spectra of pulses generated by cavity magnetrons. Now, however, the spectrum analyzer may be used to display the spectrum of any RF oscillation within its range. Since the output amplitude, over a narrow band of frequencies, is displayed vertically, and a selected range of frequencies is displayed horizontally, the complete spectrum may be observed directly. The use of a frequency meter permits the frequency of resonant cavities, echo boxes, magnetrons, and local oscillators to be measured.

The display on the CRT screen of a spectrum analyzer is a plot of amplitude versus frequency. Much useful information can be obtained from such a display. The presence or absence of signals of interest, their frequencies, frequency differences, and relative amplitudes, and the nature of their modulation, if any, may be determined from this display.

Figure 6-8 shows a typical spectrum analyzer's front panel. The controls or connections provided and an explanation of their function are as follows:

- a. Horizontal Gain. Varies the gain of the horizontal-deflection amplifier, which causes the length of the horizontal trace on the CRT screen to vary.
- b. Horizontal Position. Shifts the trace left or right on the CRT screen.
- c. Vertical Gain. Varies the gain of the vertical-deflection amplifier, which causes the height of the trace to vary.
- d. Vertical Position. Moves the trace up or down on the CRT screen.
- e. H Balance. Prevents the horizontal gain control from having a horizontal centering effect.
- f. Intensifier. Varies the intensity of the signal on the CRT screen.
- g. Center Frequency (Fine-Coarse). Controls the center frequency of the sweeper. The FINE control is used at low dispersion.
- h. Sweep Speed. Adjusts sweep repetition rate (normally between 1 and 30 Hz).
- i. Dispersion. Varies the number of megacycles displayed.
- j. Frequency Difference. Relocates the marker pip within ± 14 mc of the if center.
- k. IF Gain. Varies the sensitivity of the if amplifier.

- l. Marker Amplitude. When MARKER switch is ON, varies height of marker pip on screen.
- m. Sync Selector. Selects type of synchronization (power line frequency or external).
- n. Sync Level. Varies sync amplitude to lock the sweep generator.
- o. Power On-Off. Applies power to set.
- p. Lights (Power-Klystron). Indicates that power is applied. The klystron light should have a 60-second delay.
- q. Marker On-Off. Applies power to the marker oscillator.
- r. Focus. Focuses the trace on the CRT screen.
- s. Brightness. Varies the brightness of the signal.
- t. Scale Illumination. Controls the illumination of the graticule.
- u. Ext Sync Input. Connector for applying an external signal.
- v. Tuning. Varies the operating frequency indicated on the frequency dial.
- w. RF Attenuator. Attenuates the incoming signal down to 100 db, adjustable.

Besides being used as an indicator for frequency standards, a spectrum analyzer can also be used to:

- a. Determine pulse width, pulse shape, and frequency modulation.
- b. Check the frequency difference and/or spectra of two RF signals.

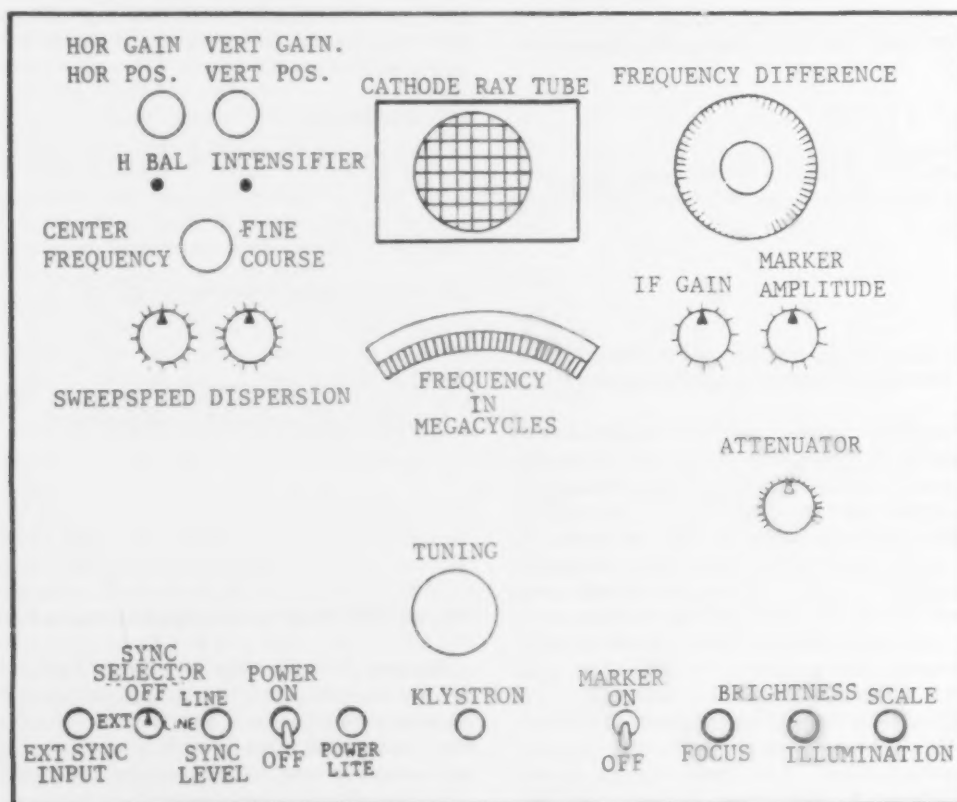


Figure 6-8. Spectrum Analyzer.

NEO 23-315

- c. Observe and measure sidebands associated with AM and FM signals.
- d. Check the frequency drift of oscillators.
- e. Determine the presence and measure the frequency of radio and/or radar signals.
- f. Locate sources of RF leakage.
- g. Check the spectrum of pulsed magnetron oscillators for pulse characteristics and frequency pulling.
- h. Determine the type of modulation in radio and/or radar signals.
- i. Check for parasitic oscillations.
- j. Check and observe the tracking of RF components of a radar system; for example, tracking transmitter and receiver.
- k. Check a transmitter or signal generator for continuous output throughout its tuning range.
- l. Measure noise spectra.
- m. Check frequency relationships of multi-frequency transmitters.

As you can see, a spectrum analyzer has many uses in our business. Hopefully, this discussion has exposed you to the possible uses and operation of a spectrum analyzer.

Exercises (051):

1. What size bandwidth does a spectrum analyzer have?
2. On a spectrum analyzer, how are frequencies displayed?
3. Once power is applied to a spectrum analyzer, how much of a delay should occur before the klystron light comes on?

052. Identify functions of a typical signal generator.

Signal Generators. A signal generator is a test device which generates an alternating current signal that is suitable for test purposes. It is, in effect, a small radio transmitter which can be constructed to generate a signal of any desired frequency. The generated signal may be modulated or unmodulated, and is used for the following tests or checks: alignment of tuned circuits, dynamic troubleshooting (signal tracking), sensitivity measurements, field-intensity measurements, and appropriate frequency measurements. The use mentioned last is limited because the signal generator is not a frequency meter and cannot be relied upon as a frequency standard. The signal generator is used principally in the alignment of tuned circuits.

Signal generators, classified by frequency, are of two types: audio frequency (AF) or radio frequency (RF). Audio-frequency generators, which are often called audio oscillators, are capable of producing signals whose

frequencies range from 20 to 20,000 cycles per second. RF generators provide practical outputs ranging from 10 kilocycles per second to 10 gigacycles per second. However, no signal generator completely covers all of the existing RF ranges. Various RF generators are available covering specified portions of the RF spectrum; many of these also have an audio output which is separately available through a front panel jack (frequencies of 400 and/or 1,000 cycles per second are generally provided). Later in this chapter, we'll cover some of these different signal generators.

The shape of the output waveforms permits a further classification of audio-frequency and radio-frequency generators. Audio-frequency generators are subdivided into sine-wave and square-wave (pulse) generators. RF generators provide either a pure radio frequency or a radio frequency with amplitude modulation, frequency modulation, or pulse modulation.

Personnel in this career field will find themselves using signal generators quite often. Many of our alignments require that a given signal be used to align a particular circuit. To ensure that the signal is correct and constant, a signal generator will be used to pump the wanted signal into the unit being tested or aligned. Using the same principle, signal generators can be used to inject a signal into a unit that has to be troubleshot. The particular equipment you're assigned to will require particular signal generators and you'll be trained to operate and use each one needed. TO 31-1-141-7 has detailed explanations of each part inside a basic signal generator and your unit should have this TO available for your use.

Exercises (052):

1. In what test is a signal generator more likely to be used?
2. How are signal generators classified?
3. What reference would you go to to obtain a more detailed explanation of signal generators?

053. Identify functions of a typical electron tube tester.

Electron Tube Testers. One of the first pieces of test equipment you'll get to use will be a tube tester. Usually, as "low person on the totem pole," you'll be assigned to run tests on suspected tubes found in your system. This section will introduce you to tube testers and we'll cover a particular one later in the chapter.

A number of different types of equipment have been developed for testing the condition of electron tubes.

Bridge-type instruments are used in laboratory work for the measurement of three important parameters of grid-controlled electron tubes: amplification factor (μ), plate resistance (r_p) and transconductance (G_m). Diode and rectifier characteristics are checked by measuring the plate current resulting from the application of a specified value of plate voltage. These bridge measurements, as well as the calculations which are a necessary part of the more complete laboratory tests, are tedious and time-consuming. To be of practical use to the technician in the field, a tube tester must provide a simple and quick appraisal of the quality of a tube. Therefore, while using the same basic principles as the laboratory measurements, checks made with field-type tube testers generally employ simplified methods.

Field-type tube testers have certain limitations; although they compare tube characteristics with a predetermined standard, they do not reveal how a tube will operate in a circuit under actual operating conditions. The final, and most accurate indication of the condition of an electron tube is its ability to function satisfactorily in the particular circuit where it is used. Many types of high-power tubes, used for transmitting and rectifying applications, cannot be checked by general purpose tube testers because of impractical power requirements. These tubes must be checked in the equipment where they are used. Tubes such as reflex klystrons, infrared image converters, and electrometer tubes must be tested by special purpose tube testers, or in the equipment where they are used. However, field-type tube testers, although limited in the completeness of their tests, are very useful aids to fast troubleshooting, since they serve to evaluate the condition of tubes most often used in communication and electronic equipment.

There are two different types of tube testers in common use in the field. These testers, which are distinguished by the main tube characteristic they check, are known as the emission-type tester and the transconductance-type tester. In addition to the main check, field-type tube testers may also be capable of performing short-circuit, noise, gas, cathode leakage, and filament activity tests.

The emission-type tube tester measures the condition of the cathode emitting surface. The end of the useful life of a tube is usually preceded by a reduction in electron emissivity; that is, the cathode becomes unable to supply the number of electrons necessary for proper tube operation. Also, if the tube has an open element, the defect prevents proper emission, and the tester indicates it as a weak or bad tube.

The emission-type tester has certain limitations and disadvantages. Since the manufacturer of a tube does not state a definite 100 percent emission point which could be used for reference, the emission test is not conclusive. High emission does not necessarily indicate a good tube, because this condition might be present in a tube with a faulty grid structure or one which has a highly emissive spot on its cathode. Very high emission has also been observed just before a tube fails completely; also, fairly low emission does not necessarily indicate in all cases that a tube is near its end-of-life point. A further disadvantage of the emission test is that gas may be liberated within the tube when AC test voltages are applied unless the test is made quickly.

Also, because the tube is not operated with its recommended DC electrode voltages in this test, it is not tested under actual operating conditions. It is also possible for a tube to show normal emission and still not operate properly. The reason for this is that the efficiency of a grid-controlled tube depends on the ability of the grid voltage to control the plate current. The emission-type tester checks only the plate current developed, and not the ability of the grid to control the plate current.

The transconductance-type tester provides a more accurate evaluation of the condition of a grid-controlled tube than the emission-type tester because it measures the amplification ability of the tube under simulated circuit conditions. The transconductance is measured and then compared with the ratings of the tube manufacturer. The meter scale of this type of tube tester is usually calibrated to indicate the transconductance (G_m), either directly in microohms or indirectly as *good*, *weak*, or *bad*. A voltage or power amplifier tube is considered defective when its transconductance decreases to 70 percent of the value stated in standard tube tables; the oscillator section of a converter tube is considered defective when its transconductance decreases to 60 percent of table values.

As stated earlier, field-type tube testers also provide tests for short-circuits, noise, gas, cathode leakage, and filament activities of a tube. These tests will be covered later on in the chapter.

Exercises (053):

1. To be of practical use to you in the field, what must a tube tester provide?
2. What are the two types of tube testers commonly used in the field?

054. Identify principles and functions of a typical echo box.

Echo Boxes. An echo box is probably one of the oldest pieces of test equipment still being used. There are echo boxes available for testing radars operating in several different frequency ranges. An echo box is a portable test unit designed for convenient field testing of radar systems. It basically consists of a tunable resonant cavity which is connected through a transmission arrangement into a radar's RF plumbing or waveguide system. The "tap-in" or probe allows the RF energy to be sampled and analyzed. Echo boxes have charts and graphs included that can be used as references to compare the sampled RF results. From these comparisons, malfunctions or misalignments can be detected. The use of echo boxes provides only relative checks of a system's operation. When more accurate, absolute measurements are required, other test sets must be used.

An echo box is a cylinder-shaped resonant cavity with a movable plunger that can be varied along the lengthwise dimension of the cavity. The cavity is hand tuned by changing the position of the plunger within the cavity. The plunger is geared to a calibrated tuning dial located on one end of the cylinder. The cavity has an input connection from the waveguide for RF energy to actuate the indicating device, usually a sensitive microammeter. This meter allows the signal strength in the cavity resonator to be measured. If the signal was monitored on a scope such as an A-scope, the transmitted or received signals could be monitored. By observing these signals, the "health" of your system can be observed. The following are some of the jobs that an echo box can be used with:

a. Transmitter frequency. With the echo box connected and the transmitter on, the echo box is tuned for peak meter reading. The calibrated dial then indicates the transmitter frequency. If the frequency is incorrect, the echo box can be set to the desired frequency and the magnetron tuned for maximum echo box meter indication. If the calibrated charts furnished with the echo box are used, precision adjustments are possible.

b. Transmitter power. As previously pointed out, the echo box meter reading varies with transmitter power. If the peak meter reading is recorded daily, any sudden changes will be indicative of transmitter trouble. With some echo boxes that contain calibrated attenuators, the actual change in power can be determined.

c. Transmitter spectrum. With the transmitter operating, the echo box attenuation is adjusted for a peak meter reading below full scale when tuned to the transmitter frequency. The echo box is then detuned to some lower frequency and then retuned, in small increments, toward and through the transmitter frequency. The meter readings for each increment are plotted on a graph. The graph is graduated with meter readings increasing vertically and frequency increasing from left to right. When the plottings are connected, they represent the spectrum output of the magnetron.

d. Receiver tuning. Ringtime measurements are taken to provide a simple method of receiver tuning. Exact procedures cannot be covered here, but will be detailed more in later volumes. The procedures, in most cases, involve tuning of the receiver local oscillator and mixer for maximum ringtime indications. If the ringtime is below standard after receiver tuning, then the receiver system probably requires maintenance.

e. Troubleshooting. Most troubles occurring in transmitter or receiver systems have characteristics that show up on the echo box meter and ringtime indications. When these indications are compared to the echo box standards and charts, the indications can be a versatile tool to a repair person.

Exercises (054):

1. Where is an echo box attached to sample a radar's RF energy?

2. How is the cavity of an echo box changed or tuned?

3. With an echo box connected, the transmitter on, and the echo box tuned for a peak meter reading, what will the calibrated dial indicate?

6-2. Specific Test Equipment

In this section, we cover some specific pieces of test equipment. The pieces chosen represent some of the more commonly used units throughout our career field. We'll start off with the AN/PSM-37 multimeter.

055. State the function(s) of selected controls and settings of the AN/PSM-37 multimeter.

AN/PSM-37 Multimeter. The AN/PSM-37 is a general purpose, ruggedized multimeter used for measuring resistance, AC and DC voltage, and AC and DC current. The maximum values that can be measured are as follows:

- a. Voltage: 1,000 volts, (5,000 volts with an additional test prod MX-1410/U).
- b. Current: 1 ampere, (10 amperes with the MX-9127/PSM-37 shunt).
- c. Resistance: 100 megohms.

Figure 6-9 shows the face areas of a typical AN/PSM-37 along with some of the attachments usable with the AN/PSM-37. As you can see, the face area of the AN/PSM-37 has lined numbers on its face. These numbers represent the following controls.

(1) **OVERLOAD INDICATOR:** The overload indicator is located just above the overload reset button (#2). When an overload has occurred which caused the overload breaker to open, a red indicator shaft appears in the transparent plastic dome. The red indicator retracts when the PUSH TO OPEN AND RESET button is depressed, and remains retracted upon release of the button if the overload has properly reset.

(2) **PUSH TO OPEN AND RESET:** This control is located adjacent to the meter on the right side of the panel. The overload circuit breaker is manually opened when this button is depressed, permitting changes in range and function settings without disconnecting the test leads from the circuit. Depressing this button also resets the overload breaker if it has been actuated.

(3) **POLARITY SWITCH:** The polarity switch is located centrally on the right side of the panel but is not marked as such. It turns the multimeter on and off and selects the nature of the measurement to be made, DC+, DC-, or AC. The "+" and "-" polarity indicates the polarity applied to the red jack when the meter reads upscale on DC measurements, and the output polarity of the red jack when making OHMS measurements.

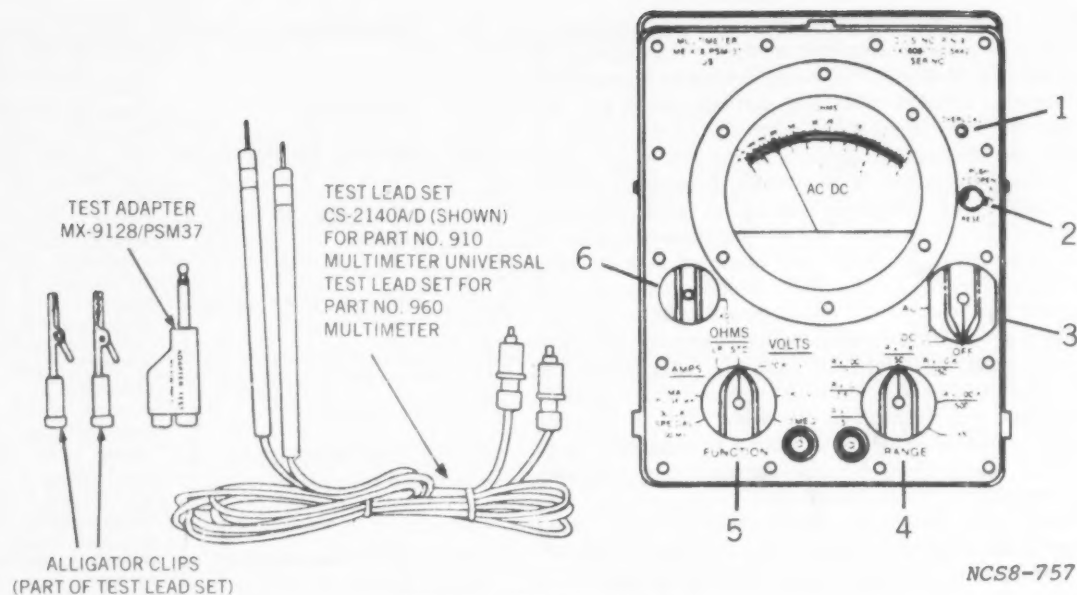


Figure 6-9. AN/PSM-37 Multimeter.

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(4) **RANGE SWITCH:** The range switch is located at the lower right of the panel. Once the **FUNCTION** switch has been set, the correct instrument range to provide an accurate scale indication is set with this range switch.

(5) **FUNCTION SWITCH:** The function switch is located at the lower left of the multimeter panel and provides the means for setting the instrument for the particular electrical characteristics to be measured.

(6) **OHMS ADJUST:** The **OHMS ADJUST** control is located centrally on the left side of the panel and used only to set full-scale deflection (needle fully to the right of the meter's scale) with the test leads shorted together prior to making resistance measurement. This control allows the operator to adjust for variations due to battery condition, temperature, and range and function settings.

Also on the multimeter's front panel, but not numbered in figure 6-9, are the two input jacks. They're located at the bottom, center of the panel between the **RANGE** and **FUNCTION** switches. The test leads also shown in figure 6-9 are normally connected into these jacks. The test leads short plugs are connected into the multimeter and the long tips (left set) are then used to probe or to be connected to the item being measured. The alligator clips can be attached to the long tips so that the leads can be attached, thus freeing the operator's hands for other jobs.

In the earlier section (6-1, Multimeters), the operations or functions of a multimeter were covered and will not be recovered here. This AN/PSM-37 multimeter performs the same functions covered in that section.

Exercises (055):

1. What is the maximum voltage that an AN/PSM-37 will read or measure using standard leads?
2. If you were assigned to measure the voltage out of a normal wall outlet, in what location/position would you place the **POLARITY** switch of an AN/PSM-37?
3. How could you attach a test lead to a resistor wire and not have to physically hold it in place?

056. State the function(s) of selected controls and settings of the Model 8800A multimeter.

Model 8800 A Multimeter. The Model 8800A Digital Multimeter is a 5½ digit instrument providing automatic or manual ranging for five DC voltage ranges (200 mV, 2V, 200V, and 1,200V), four AC voltage ranges (2V, 20V,

200V and 1,200V), and six resistance ranges (200 ohms, 2 Kohms, 20 Kohms, 200 Kohms, 2,000 Kohms, and 20 Mohms). The dual slope method of analog-to-digital (A/D) conversion, coupled with self zeroing, eliminates the display uncertainties caused by inherent A/D zero offsets. A single, digital integrated circuit uses the A/D output signal to produce the proper digit, decimal point, and polarity information for the display. What all this means is that the Model 8800A is a very stable multimeter capable of providing digital readouts of measured values. The automatic feature is extremely helpful since it will automatically change to the most appropriate scale for you.

The piano-key type control switches on the front panel make the unit easy to handle and operate. The unit's carrying handle also doubles as a tilt-stand to provide convenient viewing angles for bench use. A flashing display of 188888, used for indicating an input over range condition, also provides a convenient way of checking each digit for proper segment illumination.

Figure 6-10 shows the Model 8800A's front panel controls and indicator locations. The following is a list of those numbered items, their name, and their function:

- (1) LED display.

Provides a digital readout of the value of applied inputs.

- (2) Polarity indicator.

Displays a + (positive) or - (negative) polarity indication for corresponding DC voltage inputs.

- (3) 20 M Ω indicator.

LED indicator lights when 20 M Ω RANGE is selected.

- (4) 200 mVDC, 200 Ω indicator.

LED indicator lights when 200mVDC, 200 Ω range is selected.

- (5) Ω SOURCE HI and LO terminals.

Provide current through unknown resistance to be measured in K Ω FUNCTION.

- (6) INPUT— Ω SENSE HI AND LO terminals.

Provides terminals connections for ACV and DCV FUNCTION inputs and Ω SENSE input in K Ω FUNCTION.

- (7) GUARD terminal.

Provides connection to internal voltmeter guard.

- (8) DC ZERO adjustment.

Adjusts 8800A display for zero reading in ZERO ADJUST procedures.

- (9) FUNCTION pushbuttons.

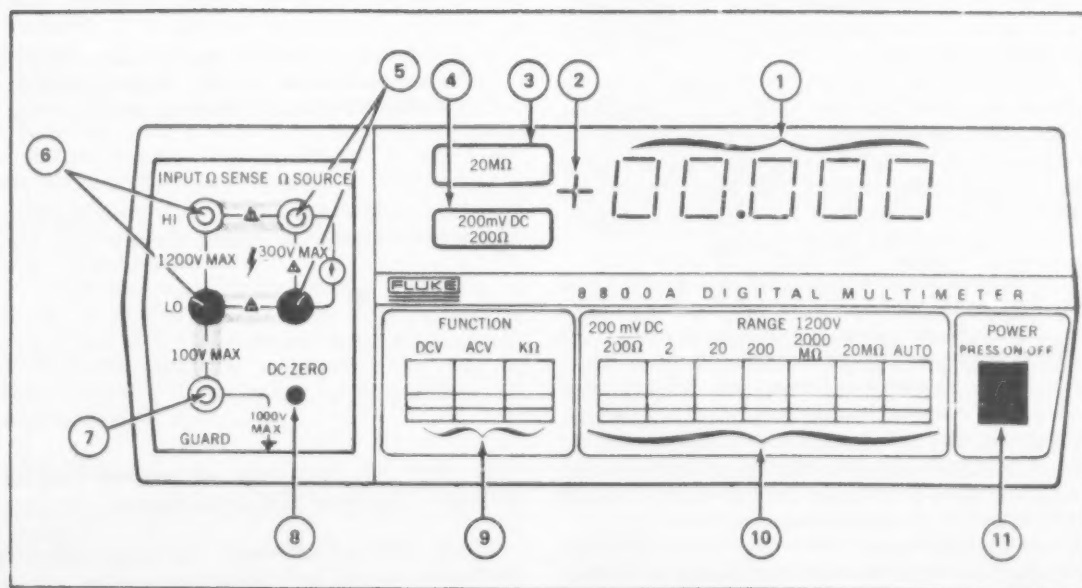
Selects the DCV, ACV OR K Ω mode of operation.

- (10) RANGE pushbuttons.

Selects discrete range of AUTO range in each function.

- (11) POWER pushbutton.

Turns instrument on or off.



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Figure 6-10. Model 8800A front controls and indicator locations.

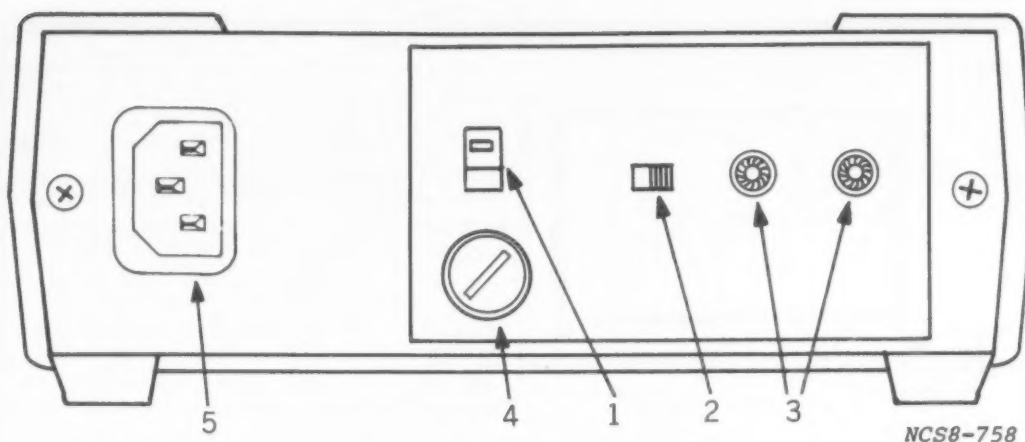


Figure 6-11. Model 8800A rear panel controls and connections.

Figure 6-11 shows the rear of the Model 8800A and the controls and connectors are identified by number, name, and function below:

- | | | |
|-----|--------------------------|--|
| (1) | SUPPLY CIRCUIT Switch. | Provides slide switch selection of the operating line voltage, 115 or 230V AC. |
| (2) | REF Switch. | Provides slide switch selection of the internal (INT) reference voltage or an external (EXT) reference voltage. The internal reference is used for making voltage measurements. The external reference is used for making DC ratio measurements. |
| (3) | EXT REF INPUT Terminals. | Used for connecting the external reference input voltage. Connect the positive input to the HI INPUT terminal and the negative to the LO INPUT terminal. |
| (4) | Fuse Holder. | Houses the line power fuse. |
| (5) | Input Power Connector | A three prong power connector for connecting the 8800A AF by way of the line cord to line power. |

Exercises (056):

- Which control or indicator lets you know the polarity of the DC voltage being used?
- To measure a 15 volt DC voltage, which keyboard switch(s) should be pressed?

- How would the REF switch on a Model 8800A be set to make normal voltage measurements?

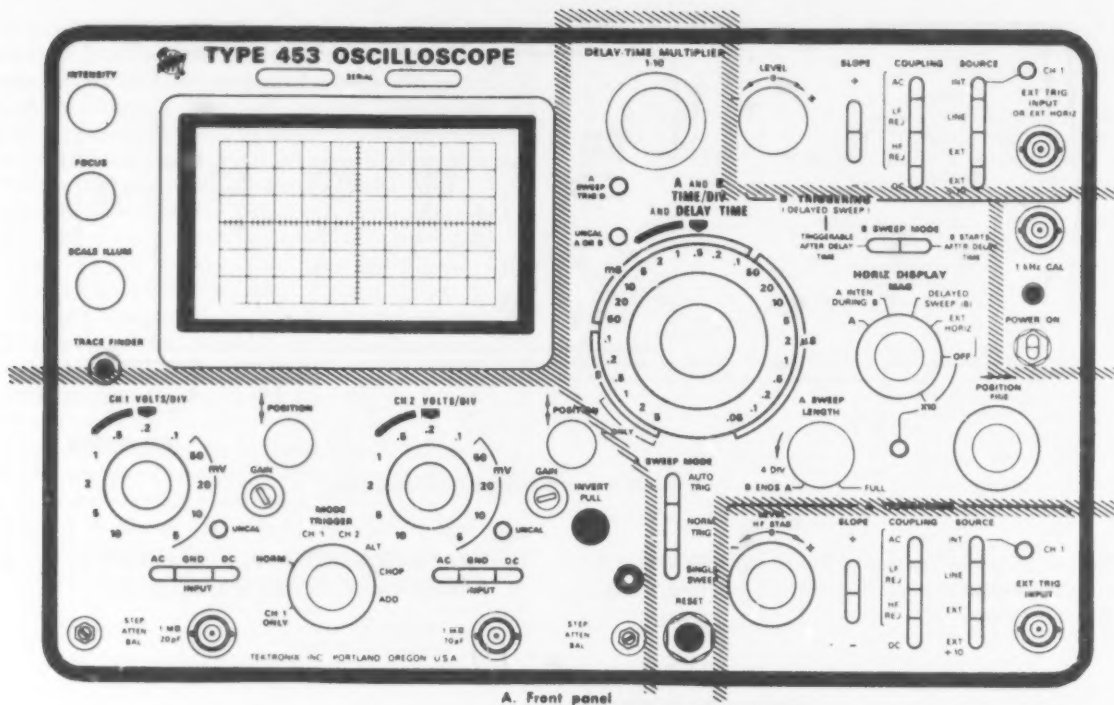
057. State the characteristics of selected controls and settings of the Type 453 oscilloscope.

Type 453 Oscilloscope. Each piece of electronic test equipment is designed to serve a purpose. Some have limited usage, others are more versatile. Among the latter is the workhorse of an electronics shop, the oscilloscope. Several oscilloscopes are authorized for use in the Air Force. For our discussion we have selected the Tektronix Type 453, and the following information was obtained from its instruction manual.

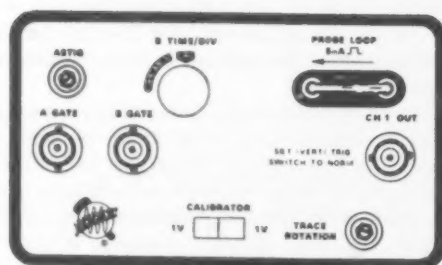
This piece of equipment is transistorized, portable, and designed to operate in a wide range of environmental conditions. Because of these factors, the 453 oscilloscope is perhaps one of the more enjoyable oscilloscopes to use.

Operating principles and procedures. Figure 6-12 is an illustration of the control position layout of this oscilloscope. Use your imagination and divide panel A into four quarters. The top left quarter has the CRT (scope) and to its left, the scope's controls. Notice that the scope's face has grid markings on it. Those markings will later be used to help you count voltage changes, time, etc. The lower left quarter has controls for each of the two channels (A and B) along with input jacks and controls. The lower half of the lower right quarter has the A triggering controls and indicators along with the External Trigger Input. The right mid-section of the panel has the sweep controls. The upper half of the upper right quarter has the B triggering controls. Look over these controls and get familiar with their names and their general location so that the following information will be easier to follow.

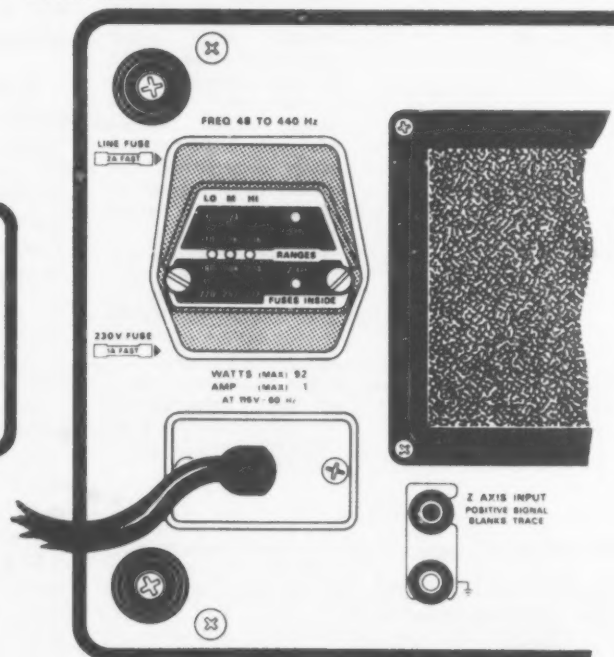
Oscilloscope inputs. The machine accepts inputs ranging from a DC level up to 50 MHz. Input coupling switches (AC-GND-DC) shown in sections "channel 1" and "channel 2" allow a choice of coupling. For DC levels,



A. Front panel



B. Side panel



C. Rear panel

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Figure 6-12. Controls for Type 453 oscilloscope.

the DC position is naturally selected but is also selected for AC signals below 16 Hz, as these would be attenuated too much in the AC position. In the AC position, the DC component of the input signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about 1.6 Hz. Therefore, you can expect some low-frequency distortion. The GND position provides a ground reference at the input of the oscilloscope. The GND position can also pre-charge the coupling capacitor to the average voltage level of the signal applied to the input connector. This allows you to measure the AC component of signals having both AC and DC components.

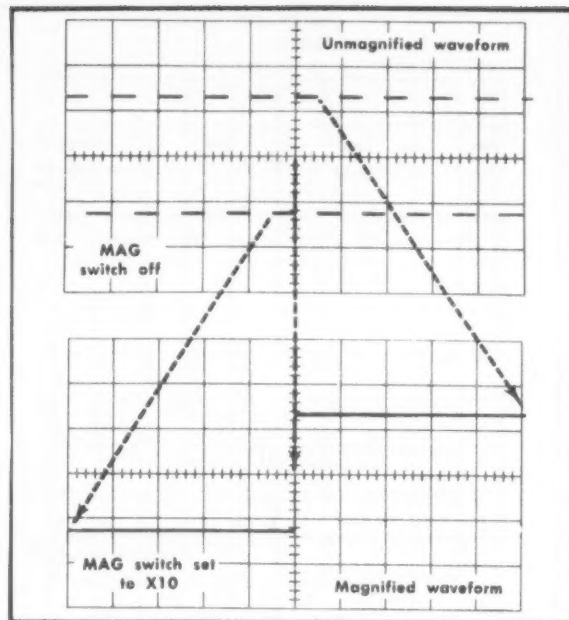
Sweep-triggering selection. An input signal is not all that is required; you must also trigger the sweep. The source of the internal trigger signal is selected by the TRIGGER MODE switch. The INT position uses a triggering signal from the vertical deflection system. When LINE position is chosen, a sample of the powerline frequency is used to trigger the sweep. This is useful in displaying a line frequency component in a complex waveform. The EXT position is used for triggering the sweep by an external signal. The external trigger must be time related to the displayed signal for a stable display. External triggering can be very useful when you are signal tracing in amplifiers, phase-shifting networks, and waveshaping circuits. Occasionally, it is desirable to broaden the range of the triggering LEVEL control. The EXT $\div 10$ position attenuates high-amplitude external signals 10 times. The LEVEL and SLOPE controls determine what portion of the trigger starts the sweep circuits. Coupling the trigger signal to the trigger circuit is the function of the 4-position COUPLING switch.

Single-sweep operation. This mode of operation is used when the signal to be displayed is not repetitive or variable in amplitude, shape, or time. The single-sweep mode can be used to set up a nonrepetitive signal for photographing.

Single-trace and dual-trace operation. The 453 oscilloscope can display a single trace in the channel 1 (CH 1) or channel 2 (CH 2) mode. However, when two input signals are to be compared, the MODE TRIGGER selector may be placed to the ALTERNATE (ALT) or CHOPPED (CHOP) position. Both modes produce two traces which alternate between CH 1 and CH 2 with each sweep across the CRT. The ALT mode can be used at all sweep rates, but the CHOP mode provides a more satisfactory display at sweep rates below a 50-microsecond/division.

Horizontal sweep controls. The use of the A and B TIME DIV and DELAY-TIME controls will be described in more detail in a later objective. The A and B TIME/DIV switches select calibrated sweep rates for the sweep generators. The A and B VARIABLE controls provide continuously variable sweep rates between the settings of the TIME/DIV switches.

The X10 position of the magnifier (MAG) switch expands the sweep 10 times. The center division of the unmagnified display is the portion visible on the screen in the magnified form (see fig. 6-13). When the MAG switch is set to the X10 position, divide the A and B TIME/DIV switch setting by 10. For example, if the TIME/DIV switch is set to .5 microsecond, the magnified sweep rate is 0.05 microsecond/division.



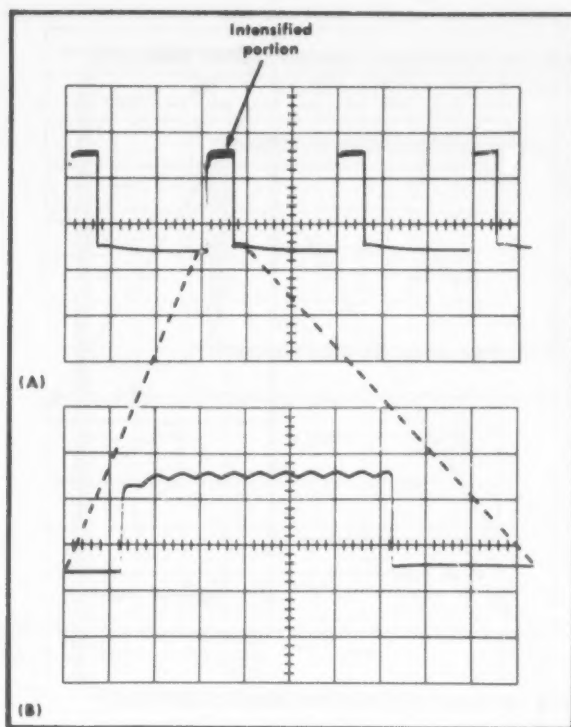
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Figure 6-13. Operation of sweep amplifier.

The delayed sweep (B sweep) is operable in the A INTEN DURING B and DELAYED SWEEP (B) positions of the HORIZ DISPLAY switch. The A sweep rate along with the DELAY TIME MULTIPLIER dial setting determines the time that the B sweep is delayed. The sweep rate of the delayed portion is determined by the B TIME/DIV (DELAYED SWEEP) switch setting on the side panel (fig. 6-12,B).

In the A INTEN DURING B position, the display is similar to figure 6-14. The amount of delay time between the start of A sweep and the intensified portion is determined by the setting of the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial. The intensified portion is produced by the B sweep. When the HORIZ DISPLAY switch is set to DELAYED SWEEP (B), only the intensified portion, as viewed in the A INTEN DURING B position, is displayed on the screen at the sweep rate determined by the B TIME/DIV switch (fig. 6-14,B).

B sweep mode. The B sweep mode switch provides two modes of delayed sweep operation. Figure 6-15 illustrates the difference between these two modes. In the B STARTS AFTER DELAY TIME position, the B sweep is presented immediately after the delay time (fig. 6-15,A). The B sweep is triggered at a selected point on A sweep to provide the delay time (B sweep essentially free-running). Since the delay time is the same for each sweep, the display appears stable. In the TRIGGERABLE AFTER DELAY TIME position, the B sweep operates only when it is triggered (by trigger circuits) after the selected delay time (fig. 6-15,B). The B triggering controls operate as described in this section.



(A) INTEN DURING B display
(B) DELAYED SWEEP (B) display

Figure 6-14. Delayed sweep display.

Delayed sweep operation. To obtain a delayed sweep display, use the following procedure:

- Obtain a stable display with the HORIZ DISPLAY switch set to A.
- Set the HORIZ DISPLAY switch to A INTEN DURING B.
- Set the B SWEEP MODE switch to the desired setting. If TRIGGERABLE AFTER DELAY TIME is selected, correct B triggering is also necessary.
- Set the delay time with the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial.
- Pull the DELAYED SWEEP (B TIME/DIV) knob out, and set to the desired sweep rate.
- If the TRIGGERABLE AFTER DELAY TIME position is used, check the display for an intensified portion. An absence of the intensified zone indicates that B sweep is not correctly triggered.
- Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). The intensified zone shown in the A INTEN DURING B Position is now displayed at the sweep rate selected by the B TIME/DIV switch.

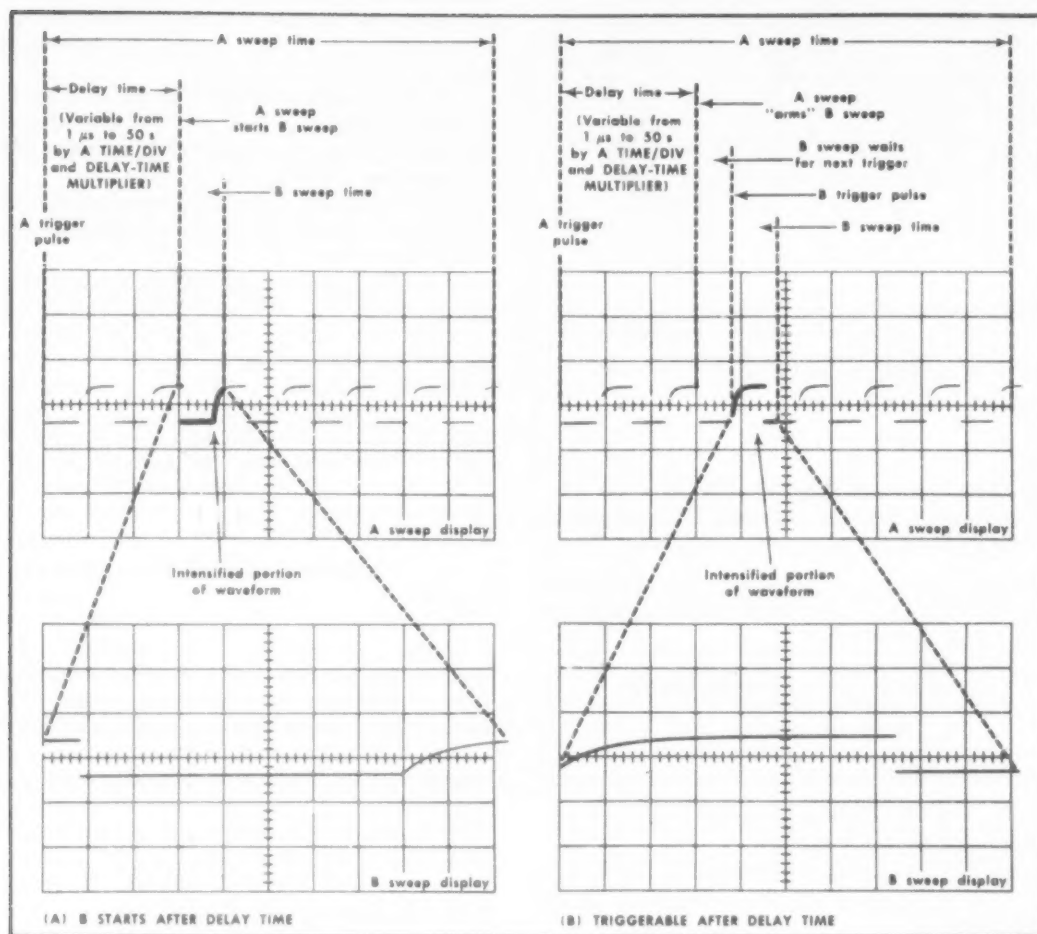
A sweep length. The A SWEEP LENGTH control is most useful when used with a delayed sweep. As the control is rotated counterclockwise from the FULL position, the

length of the A sweep decreases (sweep rate remains constant) until it is about four division long in the counterclockwise position (not in B ENDS A detent). The B ENDS A position produces a display that ends immediately following B sweep if the B sweep ends before the normal end of A sweep. The A SWEEP LENGTH control is used to increase the repetition rate of delayed sweep displays.

To use the A SWEEP LENGTH control, set the HORIZ DISPLAY switch to A INTEN DURING B and set the delay time and delayed sweep rate in the normal way. Turn the A SWEEP LENGTH control counterclockwise until the sweep ends immediately following the intensified portion on the display. Now set the HORIZ DISPLAY switch to DELAYED SWEEP (B). This method provides the maximum repetition rate for a given delayed sweep display. In the B ENDS A position, the maximum delayed sweep repetition rate is maintained automatically.

Exercises (057):

- Give the frequency range of the Type 453 oscilloscope.
- What are the positions on the INPUT COUPLING switch?
- State the types of triggering available with the Type 453 oscilloscope.
- When would it be desirable to use the ALT position of the MODE TRIGGER selector?
- If you need to view twice as many sine waves as are presently displayed, which control should you use to change the sweep rate? (You are in an undelayed mode without magnification.)
- If the TIME/DIV switch were on 2 microseconds with the MAG switch set to 10X, calculate what the magnified sweep rate would be.
- Which controls are responsible for varying the time interval between the start of a sweep and an intensified area of that sweep?



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Figure 6-15. Comparison of delayed sweep modes.

058. Identify the control settings necessary to measure specified voltages, using the Type 453 oscilloscope.

Basic applications. The Type 453 Tektronix oscilloscope is a versatile piece of equipment. One of its valuable features is its ability to measure voltages.

Peak-to-peak voltage measurements—AC. To make a peak-to-peak voltage measurement, use the following procedure:

- (1) Connect the signal to either INPUT connector.
- (2) Set the MODE switch to display the channel used.
- (3) Set the VOLTS/DIV switch to display about five divisions of the waveform.
- (4) Set the INPUT COUPLING switch to AC.

NOTE: For low-frequency signals below about 16 hertz, use the DC position.

(5) Set the A TRIGGERING controls to obtain a stable displays. See the TIME/DIV switch to a position that displays several cycles of the waveform.

(6) Turn the vertical POSITION control so that the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line and the top of the waveform is in the viewing area. Move the display with the horizontal POSITION control so that one of the upper peaks lies near the center vertical line (fig. 6-16).

(7) Measure the divisions of vertical deflection from peak to peak. Make sure the VARIABLE VOLTS/DIV control is in the CAL position.

NOTE: This technique may also be used to make measurements between two points on the waveform rather than from peak to peak.

(8) Multiply the distance measured in step (7) by the

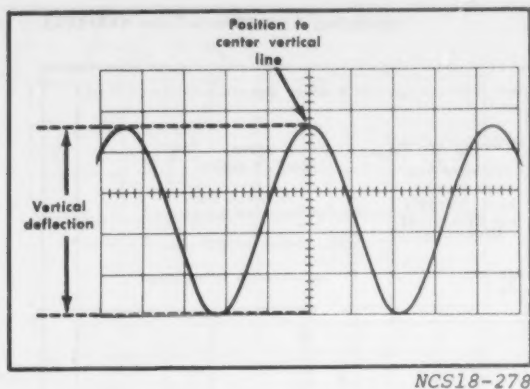


Figure 6-16. Measuring peak-to-peak voltage of a waveform.

VOLTS/DIV switch setting. Also include the attenuation factor of the probe, if any.

EXAMPLE: Assume a peak-to-peak vertical deflection of 4.6 divisions (fig. 6-16) using a 10X attenuator probe and a VOLTS/DIV switch setting of .5.

Using the formula:

$$\text{Volts peak to peak} = \text{vertical deflection (divisions)} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

$$\text{Volts peak to peak} = 4.6 \times 0.5 \times 10$$

The peak-to-peak voltage is 23 volts.

Instantaneous voltage measurements—DC. To measure the DC level at a given point on a waveform, use the following procedure:

- (1) Connect the signal to either INPUT connector.
- (2) Set the MODE switch to display the channel used.
- (3) Set the VOLTS/DIV switch to display about 5 divisions of the waveform.
- (4) Set the INPUT COUPLING switch to GDN.
- (5) Set the A SWEEP MODE switch to AUTO TRIG.
- (6) Position the trace to the bottom line of the graticule or other reference line. If the voltage is negative with respect to ground, position the trace to the top line of the graticule. Do not move the vertical POSITION control after this reference line has been established.

NOTE: To measure a voltage level with respect to a voltage rather than ground, make the following changes in step (6). Set the INPUT COUPLING switch to DC and apply the reference voltage to the INPUT connector. Then position the trace to the reference line.

(7) Set the INPUT COUPLING switch to DC. You can check the ground reference line at any time by switching to the GND position (except when using a DC reference voltage).

(8) Set the A TRIGGERING controls to obtain a stable display. Set the TIME/DIV switch to a setting that displays several cycles of the signal.

(9) Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured. For example, in figure 6-17, the measurement is made between the reference line and point A.

(10) Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line, negative (when the INVERT switch is pushed in if you are using channel 2).

(11) Multiply the distance measured in step (9) by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if any:

EXAMPLE: Assume the vertical distance measured is 4.6 divisions (fig. 6-17), the waveform is above the reference line, and you are using a 10X attenuator probe and a VOLTS/DIV setting of 2.

Using the formula:

$$\text{Instantaneous Voltage} = \text{vertical distance (divisions)} \times \text{polarity} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

$$\text{Instantaneous voltage} = 4.6 \times +1 \times 2 \times 10$$

The instantaneous voltage is + 92 volts.

Voltage comparison measurements. In some applications, you may need to establish a set of deflection factors other than those indicated by the VOLTS/DIV switch. This is useful for comparing signals to a reference voltage amplitude. To establish a new set of deflection factors based upon a specific reference amplitude, proceed as follows:

(1) Apply the reference signal of known amplitude to either INPUT connector. Set the MODE switch to display the channel used. Using the VOLTS/DIV switch and the VARIABLE control, adjust the display for an exact number of divisions. Do not move the VARIABLE VOLTS/DIV control after obtaining the desired deflection.

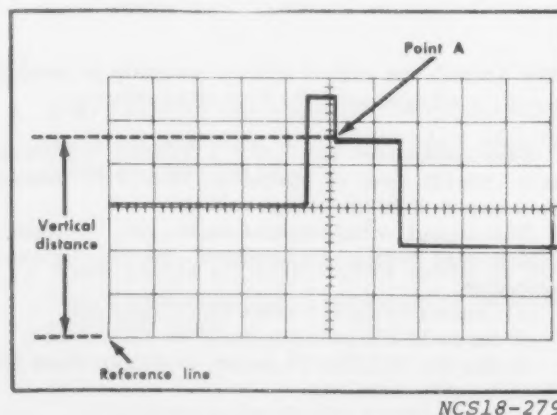


Figure 6-17. Measuring instantaneous DC voltage with respect to a reference.

(2) Divide the amplitude of the reference signal (volts) by the product of the deflection in divisions (established in step (1)) and the VOLTS/DIV switch setting. The result is the deflection conversion factor.

$$\text{Deflection conversion factor} = \frac{\text{reference signal amplitude (volts)}}{\text{deflection (divisions)} \times \text{VOLTS/DIV setting}}$$

(3) To establish an adjusted deflection factor at any setting of the VOLTS/DIV switch, multiply the VOLTS/DIV switch setting by the deflection conversion factor established in step (2).

$$\text{Adjusted deflection factor} = \text{VOLTS/DIV setting} \times \text{deflection conversion factor}$$

This adjusted deflection factor applies only to the channel used and is correct only if the VARIABLE VOLTS/DIV control is not moved from the position in step (1).

(4) To determine the peak-to-peak amplitude of a signal compared to a reference, disconnect the reference and apply the signal to the INPUT connector.

(5) Set the VOLTS/DIV switch to a setting that will provide enough deflection to make the measurement. Do not readjust the VARIABLE VOLTS/DIV control.

(6) Measure the vertical deflection in divisions and determine the amplitude by the following formula:

$$\text{Signal amplitude} = \text{adjusted deflection factor} \times \text{deflection (divisions)}$$

EXAMPLE: Assume a reference signal amplitude of 30 volts, a VOLTS/DIV setting of 5 and a deflection of 4 divisions. Substituting these values in the deflection conversion factor formula (step (2)):

$$\text{Deflection conversion factor} = \frac{30\text{V}}{4 \times 5\text{V}} = 1.5$$

Then, with a VOLTS/DIV switch setting of 10, the adjusted deflection factor (step (3)) is:

$$\text{Adjusted deflection factor} = 10\text{V} \times 1.5 = 15\text{volts/division}$$

To determine the peak-to-peak amplitude of an applied signal that produces a vertical deflection of 5 divisions, use the signal amplitude formula (step (6)):

$$\text{Signal amplitude} = 15\text{V} \times 5 = 75\text{volts}$$

Exercises (058):

1. What voltage checks or measurements can you make with the Type 453 oscilloscope?
2. With a reference signal amplitude of 20 volts, a VOLTS/DIV setting of 2, and a deflection of 5 divisions, what is the deflection conversion factor?

3. When checking a waveform with a 10x probe and the VOLTS/DIV setting on 5, you find that the waveform covers 3.5 divisions above the reference line. What is the instantaneous voltage?

4. In checking an AC voltage for peak-to-peak measurement, in what position must the VARIABLE VOLTS/DIV control be?

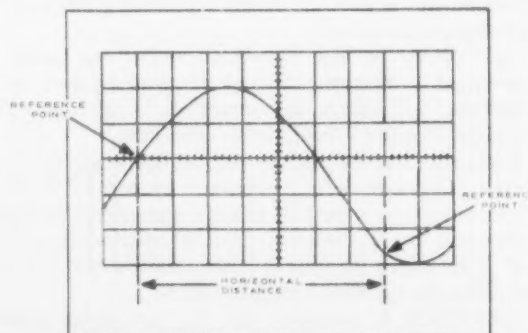
5. What is the peak-to-peak voltage of a signal with a display of 5.4 vertical divisions, a VOLTS/DIV setting of 2, and a probe attenuation of 20?

059. Using the Type 453 oscilloscope, identify the proper settings of the selected control position needed for making time and frequency measurements.

Time and frequency measurements. Time and frequency measurements comprise a large percentage of oscilloscope usage. They constitute the basis for determining most equipment malfunctions. Learning how to interpret the oscilloscope display should have high priority on your training schedule.

Time duration measurements. The waveforms that are most often measured are square waves, sine waves, and triggers. Very rarely are the more complex patterns, such as Lissajous figures, viewed. Proper positioning of the waveform under inspection is paramount because there may be some distortion or nonlinearity of the sweep speed. Because of this, it is desirable to measure only that part of the waveshape beginning 1 division from the edge of the graticule. The graticule is the plastic overlay upon which a grid is etched for reference purposes. Figure 6-18 shows the grid over the CRT face with a sine wave displayed.

The vertical amplitude is set by the VOLTS/DIV switch for about 5 divisions. Sweep stabilization is achieved with the A TRIGGERING controls. The sweep speed (set by the



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Figure 6-18. Measuring time duration.

TIME/DIV switch) must contain the desired waveform within 8 divisions on the grid. Positioning the waveform is a function of the VERT POSITION and HORIZ POSITION controls: The beginning of the waveshape is placed at a reference point on the grid and the number of horizontal divisions is counted to the second time reference point. Be sure that the A VARIABLE controls is in the CAL Position; otherwise the TIME/DIV switch will not be accurate. A simple multiplication of the TIME/DIV switch sweep-speed position by the number of grid divisions determines the time between the grid reference points. If the MAGNIFIER switch is ON, the product must be divided by 10.

EXAMPLE 1: Assume that the difference between the time measurement points is 7 divisions (fig. 6-18) and the TIME/DIV switch is set at 50 microseconds with the MAGNIFIER at X10.

Using the formula:

$$\text{Time duration} = \frac{\text{Horizontal distance (divisions)} \times \text{TIME/DIV setting}}{\text{magnification}}$$

Substitute the given values:

$$\text{Time duration} = \frac{7 \times 50 \mu\text{sec}}{10}$$

$$\text{Time duration} = 35 \text{ microseconds}$$

Frequency measurements. The procedure we used in determining time duration can also be used to measure the frequency of a periodically recurring waveshape. From your basic electronic training, you should remember that frequency is the reciprocal of time. Assuming that the entire sine wave falls within 7 grid divisions and the sweep speed remains the same as in example 1, the formula becomes:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{35 \mu\text{s}} = 28.571 \text{ kHz}$$

Rise-time measurements. Another consideration you have to make in diagnosing malfunctions is that of the rise time and fall time of a particular signal. This factor becomes very important in dealing with high-speed digital switches. Generally, the area under measurement is within the 10-to-90-percent points of the rise time. Fall time is measured the same way except the trailing edge of the waveform is measured.

The sweep of the waveform under test must be established so that the 10- and 90-percent points of the waveform fall within the innermost 8 divisions. The TIME/DIV control is used for this procedure.

Determine the 10- and 90-percent points on the rising portion of the waveform, as shown in figure 6-19. Place the 10-percent point at the first grid line and count horizontally to the grid line that intersects the 90-percent point of the waveform. Using the time duration formula, you may now determine the rise time of a given signal.

EXAMPLE 2: Assume that the horizontal distance between the 10- and 90-percent points is 4 divisions (fig. 6-16) and the TIME/DIV switch is set to 5 microseconds with the MAGNIFIER switch set to X10.

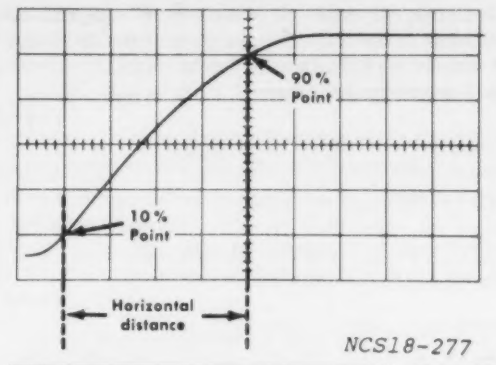


Figure 6-19. Measuring rise time.

Substituting the given values in the formula for time duration, the equation becomes:

$$\text{Rise time} = \frac{4 \times 5 \mu\text{sec}}{10} = 2 \text{ microseconds}$$

Time-difference measurements. The dual-trace capability of the Type 453 oscilloscope lends itself to measuring differences in time between the two signals. Normally, the reference signal precedes the comparison signal in time. Refer to figure 6-20. The dual-trace presentations are set for the same polarity, a vertical display of 4 to 5 divisions, and a sweep speed that separates the signal reference points by 3 or more divisions. POSITION controls center each waveform. Emphasis is placed upon using the HORIZ POSITION control to have the reference waveform cross the center horizontal line at a vertical grid line. The time difference between the two reference points can easily be measured.

EXAMPLE: Assume that the TIME/DIV switch is set to 20 microseconds, the MAGNIFIER switch to N10, and the horizontal difference between the waveform reference points is 5.5 divisions.

$$\text{Time difference} = \frac{\text{TIME/DIV setting} \times \text{horizontal difference (divisions)}}{\text{magnification}}$$

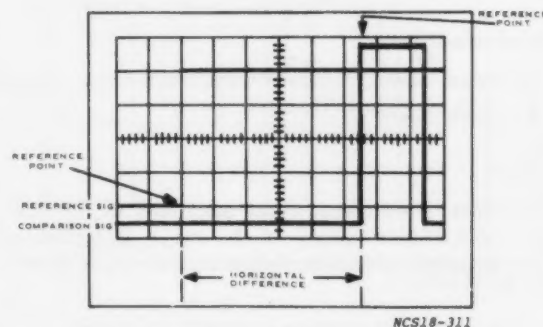


Figure 6-20. Measuring time difference between two signals.

Substituting the given values:

$$\text{Time difference} = \frac{20 \mu\text{sec} \times 5.5}{10}$$

$$\text{Time difference} = 11 \text{ microseconds}$$

Exercises (059):

1. What effect does the MAG X10 switch have on the sweep speed?
2. What is the effect of positioning a waveform too close to the edge of the CRT?
3. In what position must the A VARIABLE control be in order for the TIME/DIV switch to be accurate?
4. Given a positive square wave with 6 grid divisions between the reference points, find the time duration of the area under inspection when the TIME/DIV switch is on 50 microseconds and the MAG switch is off.
5. Solve for the frequency when the TIME/DIV switch is on 1 ms and the sine wave covers 6 horizontal divisions on the grid. The MAG switch is on X10.
6. The rise time of a signal is supposed to be .33 microsecond. The MAG switch is on X10 position. The 10- and 90-percent points fall 3 divisions apart. When will the TIME/DIV switch be set to view the signal under these conditions?
7. Describe the positioning of a reference signal on the CRT when the time relationship is being compared to another signal.

060. Identify the control settings needed to use the delayed sweep features of a Type 453 oscilloscope.

Displaying complex signals using the delayed sweep. Accurate time measurements can be made using the delayed sweep mode. This is the mode to use to find the time difference between two pulses displayed on the same trace. You can also measure the time difference from two different sources (dual-trace) or the time duration of a single pulse.

Delayed sweep time measurements. We will discuss the fundamental procedures in setting up the oscilloscope for this mode of operation. Initial sweep settings establish an amplitude of about 4 divisions, and the sweep speed contains the entire area of interest within 8 horizontal divisions. Set the A TIME/DIV switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME. The B TIME/DIV switch should be set at 1/100 of the A TIME/DIV sweep rate, producing an intensified portion of about 0.1 division in length. The intensified portion can be moved along the trace by the DELAY-TIME MULTIPLIER dial. Adjust the dial until the pulse or signal starts at one of the vertical grid lines on the graticule; note the dial reading. Now, turn the dial until the second pulse appears at the same position as the first. Again note the dial reading. Subtract the first dial setting from the second, and multiply the result by the delay time shown by the A TIME/DIV switch. This is the time interval between pulses.

EXAMPLE: Assume that the first dial setting is 1.31, and the second dial setting is 8.81 with the A TIME/DIV switch set to 0.2 microsecond (fig. 6-21).

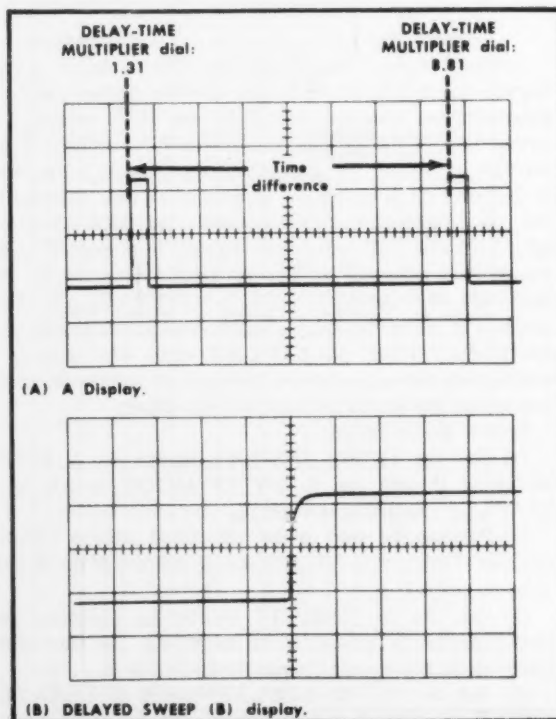
$$\text{Time difference} = (\text{second dial setting} - \text{first dial setting})$$

$$\text{Time difference} \times \text{delay time (A TIME/DIV setting)}$$

Substituting the given values:

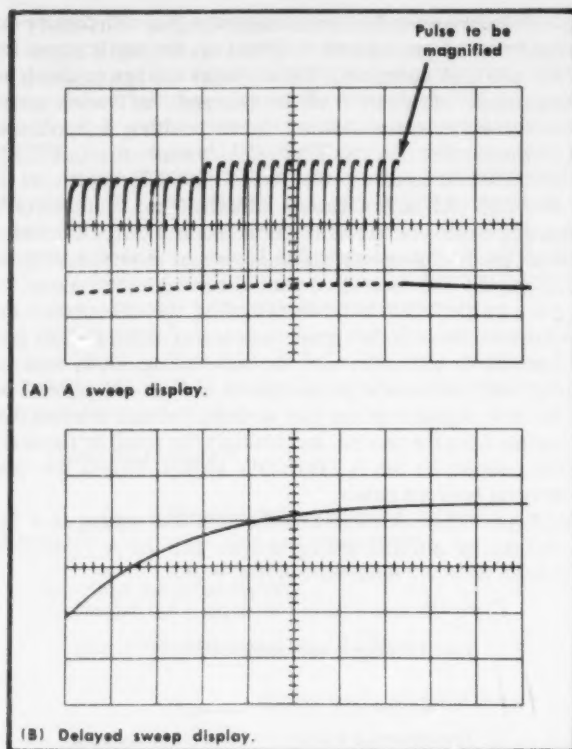
$$\text{Time difference} = (8.81 - 1.31) \times 0.2 \text{ microsecond}$$

$$\text{Time difference} = 1.5 \text{ microsecond}$$



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Figure 6-21. Measuring time difference using delayed sweep.



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Figure 6-22. Using delayed sweep for sweep magnification.

Delayed sweep magnification. The delayed sweep feature of the Type 453 can provide higher apparent magnification than is provided by the MAG switch. The sweep rate of the DELAYED SWEEP (B sweep) is not actually increased. The apparent magnification is the result of delaying the B sweep for an amount of time selected by the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial before the display is presented at the sweep rate selected by the B TIME/DIV switch. The following steps use the B STARTS AFTER DELAY-TIME position to allow the delayed portion to be positioned with the DELAY-TIME MULTIPLIER dial. The display is established showing about 4 divisions of amplitude with a sweep rate that shows the complete waveform.

Follow the next steps:

- (1) Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.
- (2) Position the start of the intensified portion with the DELAY-TIME MULTIPLIER dial to the part of the display to be magnified.
- (3) Set the B TIME/DIV switch to a setting that intensifies the full portion to be magnified. The start of the intensified trace remains as positioned in step 2.
- (4) Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). Time measurements can be made in the conventional manner. The sweep rate is determined by the setting of the B TIME/DIV switch.

You can calculate the apparent sweep magnification by dividing the A TIME/DIV switch by the B TIME/DIV switch setting.

EXAMPLE: The apparent magnification of the display shown in figure 6-22 with an A TIME/DIV switch setting of .1 ms and a B TIME/DIV switch setting of 1 microsecond is:

$$\text{Apparent magnification} = \frac{\text{A TIME/DIV setting}}{\text{B TIME/DIV setting}}$$

Substituting the given values:

$$\text{Apparent magnification} = \frac{1 \times 10^{-4}}{1 \times 10^{-6}}$$

The apparent magnification is 100 times.

Triggered delayed sweep magnification. The method of producing a sweep that we have just described may produce too much jitter at high-apparent magnification ranges. The TRIGGERABLE AFTER DELAY TIME position of the B SWEEP MODE switch provides a more stable display because the delayed display is triggered at the same point each time. After the sweep has been established on the scope, as described in the previous paragraphs, the B TIME/DIV switch is set to intensify the full portion to be magnified. Move the B SWEEP MODE switch to TRIGGERABLE AFTER DELAY TIME and adjust the B LEVEL control so the intensified portion of the trace is stable. If you cannot intensify the desired portion, you may not have the B TRIGGERING controls properly set or the signal does not meet the triggering amplitude requirements. If the condition cannot be remedied with the B TRIGGERING controls or with an increase in the display amplitude (lower VOLTS/DIV setting), you should trigger B sweep externally. When the correct portion is intensified, set the HORIZ DISPLAY switch to DELAYED SWEEP (B) and readjust the B LEVEL control for a stable display.

Pulse jitter measurements. In some cases, it is necessary to measure the amount of jitter on the leading edge of a pulse, or the jitter between pulses. The technique involves establishing a stable sweep and intensifying the area to be inspected. The HORIZ DISPLAY switch displays only the intensified portion when it is placed in the DELAYED SWEEP (B). Pulse jitter is shown by the horizontal movement of the pulse, shown in figure 6-23. Take into account the inherent jitter of the delayed sweep. Measure the amount of horizontal movement and multiply this distance by the B TIME/DIV switch setting to obtain the pulse jitter in time.

EXAMPLE: Assume that the horizontal movement is 0.5 divisions (fig. 6-23) and the B TIME/DIV switch setting is 0.5 microseconds.

Using formula:

$$\text{Pulse Jitter} = \text{Horizontal jitter (division)} \times \text{B TIME/DIV setting}$$

Substituting the given value:

$$\text{Pulse jitter} = 0.5 \times 0.5 \mu\text{sec} = 0.25 \mu\text{sec}$$

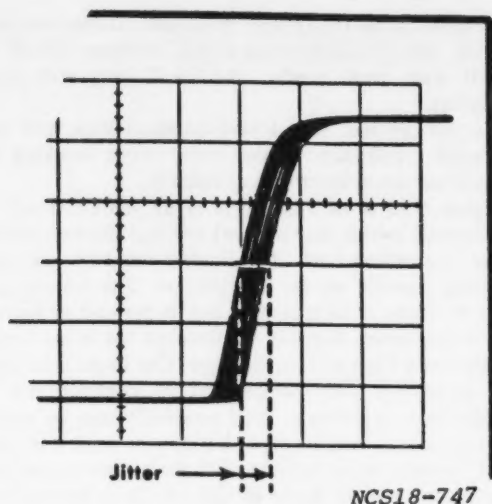


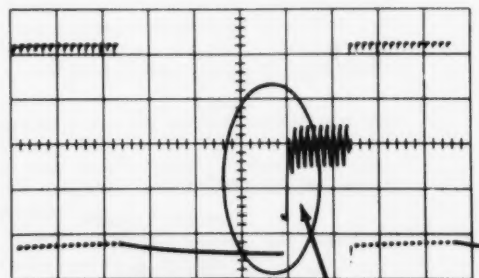
Figure 6-23. Measuring pulse jitter.

Complex signal display. Complex signals often consist of a number of individual events of differing amplitudes. Since the trigger circuits are sensitive to changes in signal amplitude, a stable display can normally be obtained only when the sweep is triggered by the event with the greatest amplitude. However, this may not produce the desired display of a lower amplitude signal that follows the triggering event. Since the delayed sweep feature does provide a means of delaying the start of the B sweep by a selected amount, the part of the waveform that contains the information of interest can be displayed. Figure 6-24 shows a complex waveform as displayed on the CRT. The circled portion cannot be viewed in any greater detail, because the sweep is triggered by the larger amplitude pulses at the start of the display and a faster sweep rate moves this area of the waveform off the viewing area. The second waveform shows the area of interest magnified 10 times using delayed sweep. The DELAY-TIME MULTIPLIER dial has been adjusted so that the delayed sweep starts just before the area of interest.

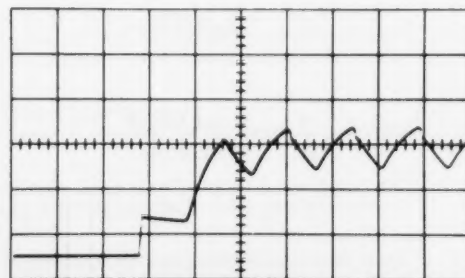
Exercises (060):

1. Describe the procedure for determining the time interval between two pulses, using the delayed sweep time method.

2. Find the time difference between two pulses. The first pulse is noted at a dial setting of 2.35 on the DELAY-TIME MULTIPLIER dial. The second pulse comes at 7.45. The A TIME/DIV switch is on 0.1 ms.
3. Determine the apparent magnification of a display from the following conditions: The A TIME/DIV switch is on 1 ms and the B TIME/DIV switch is on 5 microseconds.
4. Refer to figure 6-22. To gain an apparent magnification of 250, what must the A TIME/DIV switch setting be when the B TIME/DIV setting is on 2 microseconds?
5. Refer to figure 6-23. Pulse jitter movement occupies .75 horizontal divisions on the grid and the B TIME/DIV switch setting is 2 microseconds. What is the pulse jitter in terms of time?



(A) This portion of display cannot be viewed adequately because A sweep is triggered on larger amplitude signals at start of display.



(B) Area of interest displayed by delaying B sweep (B STARTS AFTER DELAY TIME mode).

NCS18-276

Figure 6-24. Displaying a complex signal using delayed sweep.

061. State the function(s) of selected controls and settings of the AN/USM-425 (V) 1 Oscilloscope.

AN/USM-425 (V) 1 Oscilloscope. Now that we've discussed a typical, commonly used oscilloscope (the Type 453), let's take a look at a similar model also being used in the field. The AN/USM-425(V)1 is a solid-state, dual channel, 100 megahertz bandwidth, delayed sweep, general purpose oscilloscope. Each vertical channel has ten calibrated deflection factors from 5 millivolts/division to 5 volts/division selected in a 1-2-5 sequence. The horizontal deflection system has calibrated sweep rates of 0.5 seconds/division to 0.05 microseconds/division in 22 steps. It also has delayed sweep rates of 50 milliseconds/division to 0.05 microseconds/division in 19 steps. A ten times magnifier expands each horizontal sweep rate to a maximum of 5 nanoseconds/division. An X-Y display mode is provided through vertical mode and horizontal sweep speed selection. This oscilloscope can operate in temperatures ranging from +5 to 131°F, in high humidity

(95%), and up to 15,000 feet in altitude. It only weighs 37 pounds with its accessories and is compact (7.05" tall, 13.65" wide with handle, and 24.1" long with handle extended).

As you can see, it is a very compact item with many operating capabilities needed today when working with some of our newer electronic circuitries.

Figure 6-25 is an illustration of an AN/USM-425(V)1 oscilloscope's front (top picture) and rear (bottom picture). These illustrations have identification numbers pointing to different controls on the oscilloscope. The following list gives the name of each control and its purpose or function. You'll also notice that this oscilloscope has many controls identical to a Type 453 oscilloscope. Our intent is to expose you to another oscilloscope and its controls and thus broaden your experience. You personally may be working on even another oscilloscope, but as you work with them, you'll become more familiar with their controls and more experienced overall. Refer to figure 6-25 as you study the following information.

<u>INDEX NO.</u>	<u>CONTROL, CONNECTOR, OR INDICATOR NAME</u>	<u>FUNCTION</u>
1	LINE RANGE	Selects the line voltage range on which the instrument is to be operated. The ranges are indicated on the rear panel.
2	Fuse Holder	Contains the instrument line fuse.
3	Power Cord Connector	Connects the detachable power cord to the instrument.
4	POWER	Turns the instrument on and off. Pull to turn on; push to turn off.
5	ON Indicator	Indicates when power is applied to the instrument; flashes if the line voltage drops below allowable limits.
6	INTEN	Controls the brightness of the CRT display.
7	ASTIG	Screwdriver adjustment used in conjunction with the FOCUS control to initially obtain a well defined display. Once set usually requires little or no adjustment.
8	FOCUS	Adjusts for a well defined display during normal operation.
9	TRACE ROTATION	Screwdriver adjustment used to align the trace with horizontal graticule line.
10	CALIBRATOR	Provides a 1 volt, 1 kilohertz, square wave output for setting probe compensator and checking vertical gain.
11	Graticule	Internal graticule prevents parallax errors. Rise and fall time measurement points are indicated on the left edge, and near the top and bottom horizontal portions of the graticule.
12	BEAM FINDER	Locates an off screen display. When pushed, a compressed display is visible within the graticule area. This display is independent of position controls, intensity setting, or applied signals.
13	SCALE ILLUM	Controls graticule illumination.
14	VERT MODE	Selects the operating mode for the vertical deflector system.
		CH 1: Displays only signals applied to the CH 1 input connector.
		ALT: Signals applied to CH 1 and CH 2 input connectors are alternately displayed. The alternation occurs during retrace at the end of each sweep. Useful at sweep rates of 0.5 milliseconds/division or faster. The display begins to flicker at rates slower than 0.5 milliseconds/division, therefore, the CHOP mode should be used at these rates.
		ADD: Displays the algebraic sum of the signals applied to the CH 1 and CH 2 input connectors.

INDEX NO.	CONTROL, CONNECTOR, OR INDICATOR NAME	FUNCTION
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15 VOLTS/DIV

16 VAR

17 Deflection Factor
Indicator

18 UNCAL Indicator

19 AC-GND-DC

20 Vertical Channel Input
Connectors

21 POSITION

22 INVERT
23 HORIZ DISPLAY

CHOP: Signals applied to CH 1 and CH 2 input connectors are alternately displayed at a fixed rate of about 250 kilohertz. Useful at sweep rates of 0.5 milliseconds/division or slower. At rates above 0.5 milliseconds/division the chopped segments become visible, therefore, the ALT mode should be used.

CH2 OR X-Y: Displays signals applied to the CH 2 input connector. Must be selected for X-Y operation.

TRIG VIEW or 20 MHz BW. Three position switch. When pulled out, the bandwidth of the vertical deflection system is limited to 20 megahertz, when pushed part way in the vertical bandwidth is normal, and when pushed completely in and held, the signal applied to the A Sweep trigger generator is displayed. Outer ring portion of the control selects the vertical deflection factor in a 1-2-5 sequence. Factors are calibrated when the VAR portion of the controls is in its fully clockwise detent position.

Inner knob portion of the VOLTS/DIV control. Provides continuous, variable, uncalibrated, vertical deflection factors between calibrated settings. Extends the maximum vertical deflection factor to 125 volts/division when using a 10X probe. This control must be in its fully clockwise detent position for calibrated deflection factors.

A light colored area under the VOLTS/DIV control skirt, which indicates the vertical deflection factor associated with the probe being used. Check the attenuation factor of the probe and use the correspondingly marked light colored area.

Indicates when the VAR portion of the VOLTS/DIV control is out of its fully clockwise detent position and uncalibrated deflection factors are being used.

Selects the method of coupling the input signal to the vertical input amplifier.

AC: Input signals are capacitively coupled, blocking any DC component. Low frequencies are attenuated about 3 dB at 10 hertz using a 1X probe and at 1 hertz using a 10X probe. AC coupling may cause tilting of square wave signals below about 1 kilohertz.

GND: Connects the vertical input amplifier to ground to provide a ground reference display (input signals is disconnected). Connects the input signal to ground through the AC input capacitor and a one megohm resistor to keep the input coupling capacitor precharged.

DC: Input signals are directly coupled, thus passing all components of the signal to the input amplifier.

Connects the Channel 1 and Channel 2 vertical input probes to the instrument. In the X-Y mode of operation, the CH 1 OR X input provides horizontal deflection and the CH 2 OR Y input provides vertical deflection.

Provides vertical positioning control of the display. In the X-Y mode of operation, the CH 1 OR X control positions the display horizontally and the CH 2 OR Y control positions the display vertically.

Inverts the Channel 2 display only.

Selects the mode of operation for the horizontal deflection system.

A: Horizontal deflection is provided by the A sweep generator at a rate set by A TIME/DIV. The B sweep generator (delayed sweep) is disabled.

MIXED: The first part of the sweep is displayed at a rate set by A TIME/DIV and the last part of the sweep is displayed at a rate set by B TIME/DIV. The relative amount of display controlled by each setting is determined by the setting on the DELAY TIME POS dial.

<u>INDEX</u> <u>NO.</u>	<u>CONTROL, CONNECTOR,</u> <u>OR INDICATOR NAME</u>	<u>FUNCTION</u>
		A INTEN: Horizontal deflection is provided by the A sweep generator at a rate set by A TIME/DIV. The B sweep generator produces an intensified zone on the display. The length of time the display is intensified is about ten times the B TIME/DIV setting except when A sweep ends before B sweep. The location of the intensified zone on the display is determined by the DELAY TIME POS dial setting. B DLY'd: Horizontal deflection is provided by the A sweep generator at a rate set by B TIME/DIV. The A sweep generator continues to operate. With the B sweep SOURCE set to STARTS AFTER DELAY, the start of B sweep is delayed from the start of A sweep by a time determined by the settings of A TIME/DIV and DELAY TIME POS. To calculate the delay, multiply the A TIME/DIV setting by the DELAY TIME POS dial setting.
24	POSITION	Provides horizontal positioning control of the display, except in the X-Y mode of operation when the CH 1 OR X POSITION control provides horizontal positioning.
25	A AND B TIME/DIV	Selects the sweep rate for the A and B sweep. The A sweep rate is set by rotating the outer ring portion of the control. The rate is shown between the two black lines on the clear skirt of the control. This rate is multiplied by the DELAY TIME POS setting when using the A INTEN or B DLY'D display modes. For calibrated sweep rates, the VAR knob portion of the control must be in the fully clockwise detent position. The B sweep rate is set by pulling the outer ring out and rotating it to a setting shown by the white line scribed on the ring. The X-Y mode of operation is selected with the A sweep rate control is set fully counterclockwise.
26	VAR	Inner knob portion of the A AND B TIME/DIV control. Provides continuously variable uncalibrated sweep rates between calibrated settings of the A TIME/DIV settings. Must be in its fully clockwise detent position for calibrated A sweep rates and delay times.
27	UNCAL Indicator	Indicates when the VAR portion of the A AND B TIME/DIV control is out of its fully clockwise detent position and the A sweep rates are not calibrated.
28	X10MAG	Increases the displayed sweep rate by a factor of 10. Extends the fastest sweep rate to 5 nanoseconds/division. The magnified sweep display is the center one division of the unmagnified display (0.5 division from another side of the center vertical graticule line).
29	X10 MAG Indicator	Indicates when the X10 MAG is selected.
30	DELAY TIME POS	Provides a variable B sweep delay from 0.000 to 10,000 times the setting of the A TIME/DIV control.
31	TRIG MODE	Selects the mode of operation for the A sweep trigger. AUTO: With proper trigger LEVEL and COUPLING settings, A sweep can be initiated by signals above about 20 hertz. In the absence of a triggering signal or with control misadjustments, the A sweep generator free-runs to provide a reference display. NORM: With proper trigger LEVEL and COUPLING settings, A sweep can be initiated by an input signal. In the absence of a triggering signal or with control misadjustments, the A sweep generator does not run and there is no display. SGL SWP: A momentary contact push button, which cancels previous TRIG MODE selections and selects a single sweep mode of operation. This mode operates the same as NORM, except only one sweep is displayed on a trigger signal. Another single sweep cannot be displayed until the SGL SWP push button is presented to reset the trigger circuit.
32	TRIG READY Indicator	Indicates the A sweep is reset and ready for a single sweep display when a trigger signal occurs. If the indicator is out when in the SGL SWP mode, the SGL SWP push button must be pressed to reset the trigger circuit.

INDEX NO.	CONTROL, CONNECTOR, OR INDICATOR NAME	FUNCTION
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33 SOURCE

Selects the source of trigger input signal.

STARTS AFTER DELAY (B trigger only): B sweep runs immediately after the delay time selected by the A TIME/DIV setting multiplied by the DELAY TIME POS setting. No B trigger is required. In any other B trigger SOURCE setting, a trigger is required after the delay time before B sweep will run.

NORM: Provides a trigger from the vertical deflection system. The actual source is the displayed signal. In this mode, CH 1 and CH 2 time relationship measurements are not valid and should not be used. This mode is not recommended for use in the CHOP or ALT VERT MODE because the display triggers on the channel switching transients.

CH 1: Provides a trigger from the CH 1 preamplifier. The CH 2 display may be unstable if it is not time related to CH 1.

CH 2: Provides a trigger from the CH 2 preamplifier. The CH 1 display may be unstable if it is not time related to CH 2.

LINE (A trigger only): Provides a trigger from a sample of the power-line frequency. This trigger is useful when channel inputs are time related (multiple or sub-multiple) to the power-line frequency. Also, it is useful for stabilizing a display that has a power-line frequency component on a complex waveform.

EXT: Provides a trigger from an external signal connected to the External Trigger Input connector. This trigger input must be time related to the input signals to provide a stable display.

EXT ($\div$ by 10): The same as EXT above, except the input signal is attenuated by a factor of 10.

34 COUPLING

Selects the method used to couple signals to the trigger generator.

AC: Selects capacitive coupling, which blocks DC components on the signal. Signals below about 60 hertz are attenuated.

LF REJ: Selects capacitive coupling, which blocks DC components on the signal. Signals below about 50 kilohertz are rejected. Useful for displaying high frequency components of complex waveforms.

HF REJ: Signals are capacitively coupled, which blocks the DC component. Signals below about 60 hertz and above about 50 kilohertz are attenuated. Useful for displaying low frequency components of complex waveforms.

DC: All components of the signal are coupled. Useful for displaying low-frequency or low repetition rate signals.

35 LEVEL

Selects the amplitude point on the trigger signal at which the sweep is triggered. It is usually adjusted after the trigger SOURCE, COUPLING, and SLOPE have been selected.

36 SLOPE

Selects the slope of the trigger signal on which the sweep is triggered.

OUT +: Sweep is triggered on the positive going portion of the trigger signal.

IN -: Sweep is triggered on the negative going portion of the trigger signal.

37 External Trigger Input
Connector

Connects external trigger input probe or cables to the instrument.

38 A TRIGGER HOLDOFF

Provides control of holdoff time between sweeps. Variable up to ten times the setting of the A TIME/DIV setting, except in the .2 and .5 second ranges. Useful when triggering on low repetition pulses or aperiodic signals.

Obtain the best possible display using the A sweep trigger controls before setting the hold off time.

<u>INDEX NO.</u>	<u>CONTROL, CONNECTOR, OR INDICATOR NAME</u>	<u>FUNCTION</u>
39	Ground Binding Post	External connector to chassis (earth) ground. The connector will accept cables or wires using open end solder lugs, banana plugs, or stripped wire for connection.
40	+A GATE	Provides a +5 volt positive pulse output during the A sweep time.
41	+B GATE	Provides a +5 volt positive pulse output during the B sweep time.
42	EXT Z AXIS	Connects external Z-axis inputs for CRT intensity modulation. External inputs may also be used for CRT blank providing the CRT intensity is properly set. Useful for adding time markers to a display, or when using the instrument as a peripheral display in a monitoring screen.
43	CH 2 OUT	Provides an output signal from the CH 2 pre amplifier. Useful for cascade operation (CH 2 into CH 1) to increase vertical deflection sensitivity. Also, may be used to trigger external equipment.

Exercises (061):

1. Where would you find the line fuse of the AN/USM-425(V)1 oscilloscope?
2. If the line voltage being fed to the AN/USM-425(V)1 oscilloscope drops below allowable limits, what indicator identifies this problem?
3. In the X-Y mode of operation, what controls position the display horizontally?
4. What control selects the amplitude point on the trigger signal at which the sweep is triggered?
5. What position on the SOURCE control provides a trigger from a sample of the power-line frequency?

062. State the function(s) of selected controls and settings of a Model 618C/620B Signal Generator.

Model 618C/620B Signal Generators. As we covered earlier in Section 6-1, there are times we'll need to generate a signal to inject into one of our units or systems for alignment or troubleshooting purposes. The Model 618C/620B and the 620A version signal generators all perform these functions for us. Each will have its band of frequencies but all basically have the same controls.

Figure 6-26 is an illustration showing the controls of a Model 618C/620B signal generator. The following list gives the identification number, the item's name, and then its function(s):

(1) MOD Selector. In FM EXT position, sine wave or sawtooth applied to EXT. MOD connector modulates the signal generator. In FM INT position, an internally generated sawtooth modulates the signal generator. In CW position, the signal generator is not modulated. In OFF position, the signal generator RF output is disabled. In the INT. position, the signal generator is modulated by internally generated pulses. In the EXT+ position, the signal generator can be modulated by positive pulses applied to the EXT. MOD. connector. In the EXT- position, the signal generator can be modulated by negative pulses applied to the EXT. MOD. connector. In  position the signal generator is modulated by internally generated square waves (approximately 50% duty cycle).

(2) PULSE WIDTH. Adjusts width of modulating pulse when the MOD. SELECTOR is set to INT.

(3) PULSE DELAY. Adjusts the delay time between synchronizing pulse and RF output pulse from 3 to 300 μ s.

(4) PULSE RATE. Adjusts pulse repetition rate of modulation when the MOD SELECTOR is set to INT, FM INT, or  position and the SYNC SELECTOR is in X1 position, the pulse rate is indicated by the PULSE RATE control; when the SYNC SELECTOR is in the X10 position, the pulse rate is 10 times that indicated by the PULSE RATE control.

(5) SYNC SELECTOR. In the  position, and when MOD. SELECTOR is set to INT, the signal generator may be synchronized by external sine-wave signal of 5-50 V rms applied to the SYNC IN connector. In the EXT- position, and when MOD. SELECTOR is in the INT position, the signal generator must be synchronized by negative pulses (5-50V peak-to-peak) applied to the SYNC IN connector.

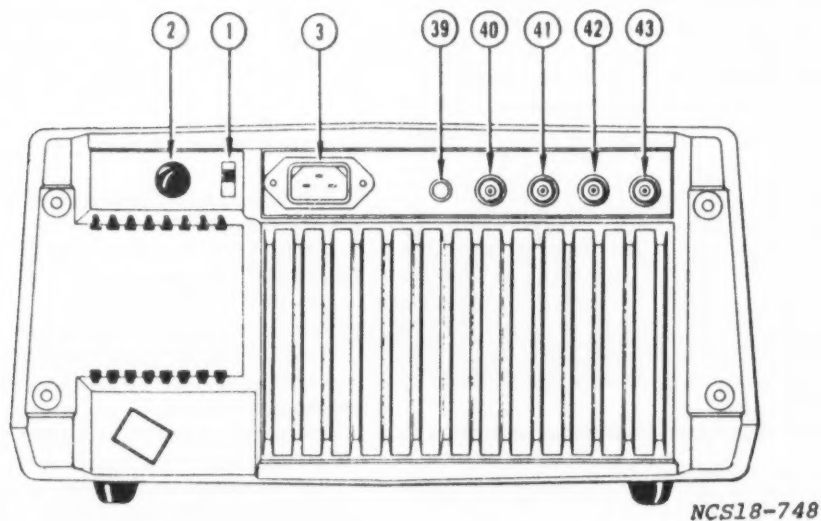
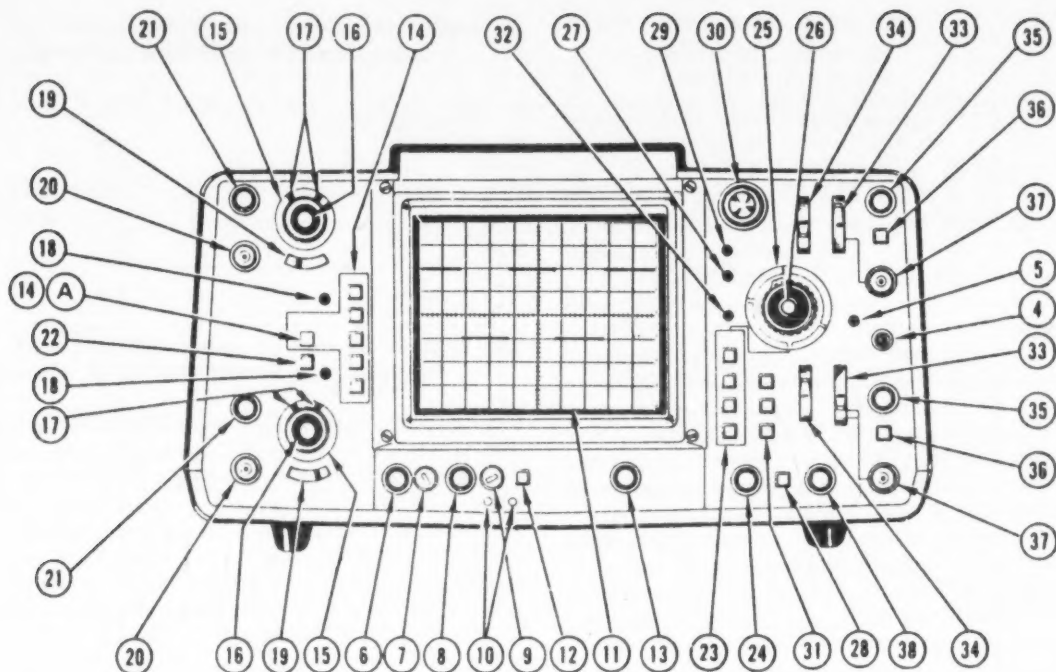


Figure 6-25. Front and rear controls, connectors, and indicators of an AN/USM-425(V)1 oscilloscope.

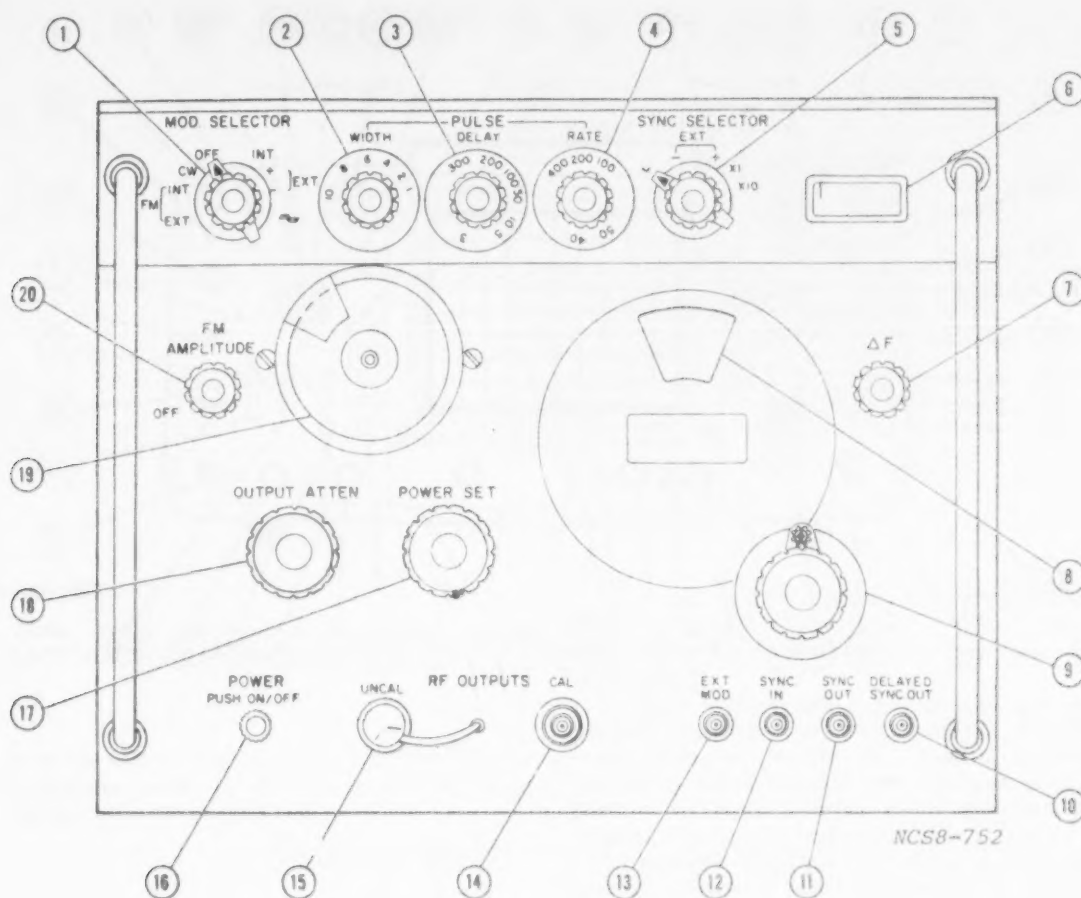


Figure 6-26. Model 618C/620B Signal Generator controls and connectors.

In the EXT+ position, and when MOD. SELECTOR is set to INT, the signal generator must be synchronized by external positive pulses (5-50 V peak-to-peak) applied to the SYNC IN connector. In the X1 position, and when the MOD. SELECTOR is set to INT, the modulation repetition rate is as indicated by the PULSE RATE control. In the X10 position, and when the MOD. SELECTOR is set for INT, the modulation repetition rate is 10 times that indicated by the PULSE RATE control.

(6) Power Meter. Indicates RF power input in dBm to attenuator.

(7) DeltaF. Provides up to 0.5 MHz adjustment of output frequency for 618C; 1.5 MHz for 620B.

(8) MGz/GHz. Indicates the RF output frequency in megahertz/gigahertz for the 618C/620B respectively.

(9) Frequency Control. Adjusts RF output frequency.

(10) DELAYED SYNC OUT. Delayed (3-300 μ s) synchronization signal is available at this connector.

(11) SYNC OUT. Undelayed synchronization output signal is available at this connector.

(12) SYNC IN. External synchronization signal is applied to this connector.

(13) EXT. MOD. External modulation signal is applied to this connector.

(14) RF OUTPUTS CAL. Source of calibrated RF power is available at this connector.

(15) RF OUTPUTS UNCAL. Uncalibrated RF output power is available at this connector.

(16) POWER. Turns the signal generator on and off.

(17) POWER SET. Adjusts the RF power input to the attenuator.

(18) OUTPUT ATTN. Adjusts RF output power to a calibrated level.

(19) Attenuator Dial. Indicates RF output level when power meter is indicating 0 dBm.

(20) FM AMPLITUDE. Adjusts the frequency deviation of the RF when using frequency modulation.

Exercises (062):

1. What control adjusts the RF output frequency?

2. How much time delay can be adjusted for between the synchronizing pulse and the RF output pulse?

3. What control adjusts the RF power input to the attenuator?

063. State the function(s) of selected controls and settings of a Model 608E/608F Signal Generator.

Models 608E/608F Signal Generators. Another signal generator often used in this career field is the Model 608E or the Model 608F. The Model 608E furnishes RF signals from 0.1 microvolt to 1 volt at 10 MHz to 480 MHz, while the Model 608F supplies RF signals from 0.1 microvolts to 0.5 volts in a frequency range from 10 MHz to 455 MHz. The RF carrier can be amplitude modulated by internally generated sine-wave signals or by externally supplied sine-wave or pulse signals. The Model 608F contains frequency control circuitry which permits the instrument to be used in phase-lock operation with the Model 8708A Synchronizer. This provision provides a stabilized output across most of the range of the instrument, with a drift factor of 2 times 10^{-7} in 10 minutes. To preserve accuracy, equipment design holds spurious modulation to a low value under all operating conditions.

The two models can use either 115V or 230V, 50 to 400 Hz line power. They measure about 13" wide, 17" high, and 21" deep and weigh about 62 pounds. When handling them, remember that they, like all test equipment, are calibrated electronic equipment and cannot stand to be abused. Damaged test equipment can cause you unnecessary work and erroneous readings.

Controls. The controls and indicators of a Model 608E/F are shown in Figure 6-27. The controls, identified by ID number, name, and function are as follows:

- (1) Cursor knob. Positions cursor on the MEGACYCLES (frequency) dial.
- (2) PERCENT MODULATION meter. Indicates the percent of modulation of the RF output signal.
- (3) Panel marker. Scribed mark for cursor alignment.
- (4) ZERO control. Screwdriver adjustment to electrically zero the PERCENT MODULATION meter.
- (5) RF OUTPUT control. Controls RF power input to the attenuator. Also controls output power levels between +7 dBm and +13 dBm in the Model 608E.
- (6) MODULATION control. Adjusts the percent of modulation of the RF output signal as observed on the PERCENT MODULATION meter.
- (7) FINE FREQ control. Used for fine frequency adjustments.
- (8) FREQUENCY RANGE switch. Five-position switch used to select the desired frequency range. Also positions the range pointer on the dial. Switch positions are as follows:

RANGE	MODEL 608E	MODEL 608F
A	10-21 MHz	10-21 MHz
B	21-43 MHz	21-44 MHz
C	43-95 MHz	44-95 MHz
D	95-215 MHz	95-210 MHz
E	215-480 MHz	210-455 MHz

(9) AC POWER lamp. Indicates when AC power is applied to the instrument.

(10) DC .25 AMP fuse. Overload protective device for the -225 VDC power supply.

(11) AC LINE fuse. Protective device between the instrument and the AC power source.

(12) AC POWER ON switch. Controls application of AC power to the instrument.

(13) FREQ CONTROL INPUT connector (Model 608F only). Input connector for the DC control voltage when the instrument is used with a Model 8708A Synchronizer.

(14) AM/PULSE MOD INPUT connector. Input connector for AM or pulse signals during external sine-wave or pulse operation. During internal sine-wave modulation, a 400 or 1000 Hz signal is available at the connector for synchronizing external equipment.

(15) UNCAL RF OUTPUT connector. Output connector in the 608E delivers an uncalibrated, unmodulated RF signal to external equipment. In the Model 608F, used with the Model 8708A Synchronizer, output connector delivers an uncalibrated FM signal.

(16) MEGACYCLES dial. Indicates selected frequency range and frequency in MHz.

(17) RF OUTPUT meter. Indicates level of RF power applied to the attenuator as selected by operation of the RF OUTPUT control. Also used in conjunction with the AMPL TRIMMER control (19) to peak the RF output signal.

(18) Frequency control. Used to select the output frequency within a frequency range as observed on the MEGACYCLES dial.

(19) AMPL TRIMMER control. A two-function control for peaking the RF output. During pulse modulation, the control is tuned (without pushing) to peak the RF output. When sine-wave or CW operations are conducted, the control is pushed and then tuned.

(20) MODULATION switch. A six-position switch that sets the instrument mode of operation. The switch positions are identified as follows:

PULSE. Sets the instrument for external pulse modulation.

PULSE SET RF OUTPUT. Used to establish the instrument operating point for external pulse modulation.

AM: Sets the instrument for external sine-wave modulation.

1000 ~: Sets the instrument for internal AM modulation of 1000 Hz.

400 ~: Sets the instrument for internal AM modulation at 400 Hz.

(21) XTAL CAL GAIN control. Controls audio level of beat-frequency output at the XTAL CAL OUTPUT connector (26).

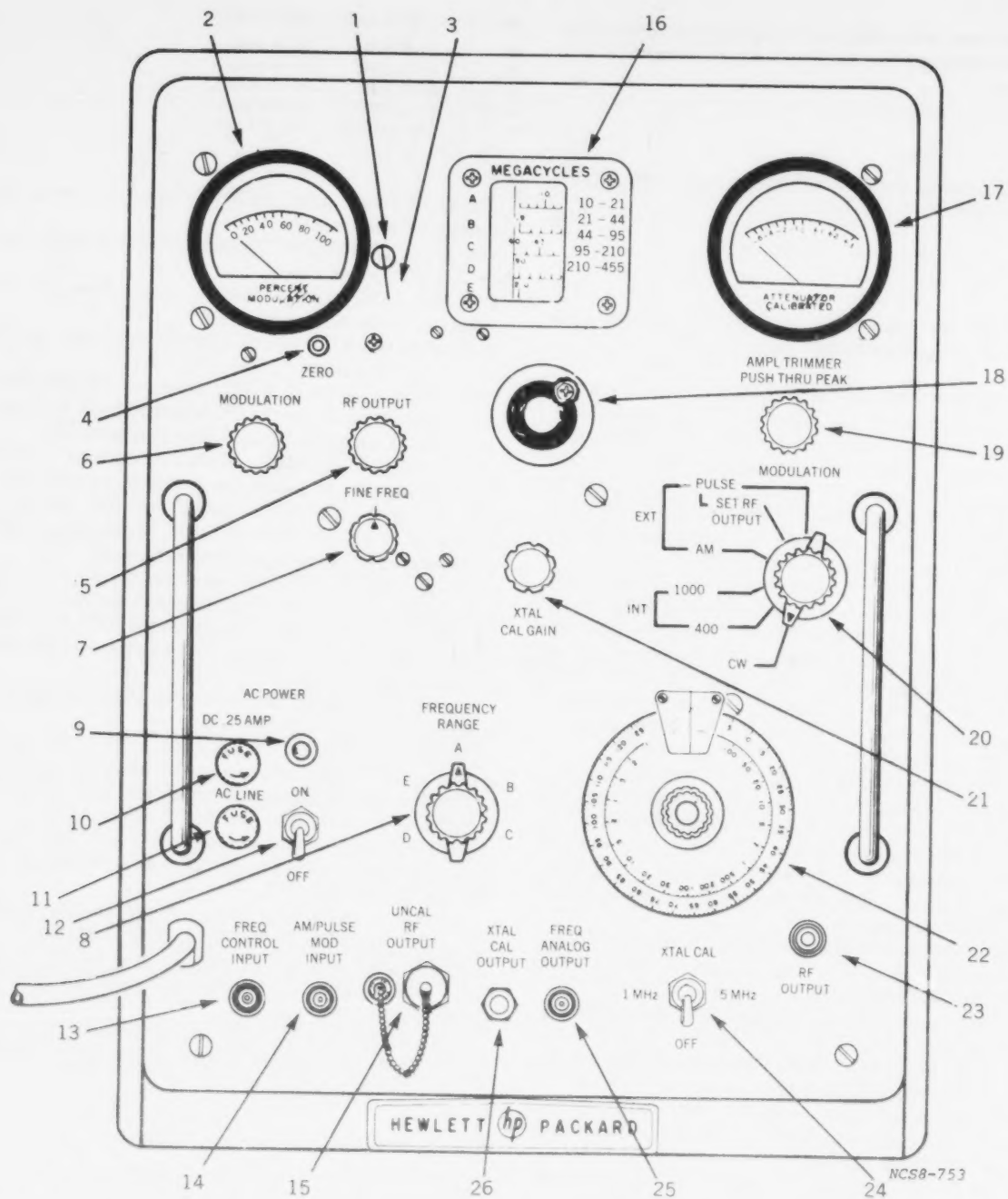


Figure 6-27. Model 608E/608F Signal Generator controls and connectors.

(22) Attenuator control. Controls RF output levels of +7 dBm and below. Output levels selected by use of the Attenuator Control are accurate as long as the RF OUTPUT meter needle indicates +7 dBm (ATTENUATOR CALIBRATED).

(23) RF OUTPUT connector. Output connector for the calibrated RF signal.

(24) XTAL CAL switch. Three-position toggle switch used when performing frequency calibrations. Switch positions are as follows:

1 MC: Provides 1 MHz checkpoints from 10 to 270 MHz.

5 MC: Provides 5 MHz checkpoints from 10-480 MHz in the Model 608E and from 10-455 MHz in the Model 608F.

OFF: De-energizes oscillator circuits.

(25) FREQ ANALOG OUTPUT connector (Model 608F only). Delivers a resistance proportional to frequency to the Model 8708A Synchronizer during phase-lock operation.

(26) XTAL CAL OUTPUT connector. Supplies calibrating signals to an operator for frequency calibration. Accommodates an earphone plug.

Operations. Operating these instruments must be done according to established procedures to prevent damage to the equipment or injury to personnel. The following steps are designed to help you understand the operation of these pieces of equipment:

Pre-operation procedures. Prior to use, certain precautions must be completed to obtain maximum accuracy during operation of the instrument. Consideration must be given to the possibility of RF loading, and calibration of the instrument is required.

CAUTION: Do not connect any source of RF or DC power to the RF OUTPUT connector on the signal generator. To do so may permanently damage the impedance-matching network in the Attenuator Section. Particular care must be observed when testing transceiver-type equipment to insure that the transmitter remains inactive while the equipment is connected to the signal generator.

NOTE: To protect the Attenuator when there is a possibility of voltage being applied to the RF OUTPUT connector, a Model 11509A Fuseholder is recommended. The fuseholder is connected between the test cable and RF OUTPUT connector.

A resistive load of 50 ohms is used at the factory during calibration of the Attenuator Control dial. Therefore, for an accurate indication of output power the external load should be 50 ohms resistive. The internal impedance of the generator is close to 50 ohms, with a maximum VSWR of 1.2 existing when the generator is terminated in 50 ohms. This VSWR will have no important effect on the accuracy of the Attenuator Control calibration. However, a severe mismatch between the instrument and load will produce a considerable difference between the output voltage selected on the Attenuator Control dial and the actual voltage impressed across the external load. Particular care should be exercised in the selection of coaxial connectors. A coaxial connector that has been improperly assembled can produce a substantial increase in the standing-wave ratio.

Turn-on procedures. Turn-on procedures are as follows:

CAUTION: Do not obstruct the ventilating louvers on the side of the instrument cabinet. Safe operating temperature requires free air flow through the louvers.

a. Set AC POWER switch (item 12) to the OFF position.

b. Check position of 115-230 volt power switch on rear of chassis.

c. Set MODULATION selector switch (item 20) to CW position.

d. Set RF OUTPUT control (item 5) to near maximum position (clockwise).

e. Set AC POWER switch to ON position.

f. Warm up equipment for 10 minutes prior to use. If greater frequency stability is required, extend warm-up period to 60 minutes.

Calibration procedures. Prior to operation, certain calibration of the instrument may be deemed necessary. The following explanations discuss frequency and power output calibration procedures.

Frequency Calibration. The frequency (MEGACYCLES) dial in the signal generators are calibrated to be accurate within $\pm 0.5\%$ for the 608E and $\pm 0.1\%$ for the 608F. To obtain higher accuracy, a crystal-controlled calibrator has been included to provide a means of calibrating the instrument at any multiple of 1 MHz between 10 and 270 MHz, or any multiple of 5 MHz across the frequency range of the instrument. Procedures to crystal-calibrate the instrument are as follows:

a. Perform turn-on procedures as previously noted.

b. Connect headphones (not supplied) to the XTAL CAL OUTPUT connector (item 26).

c. Set XTAL CAL switch (item 24) to 1 MC or 5 MC as applicable.

d. Rotate frequency control (item 18) until MEGACYCLES dial (item 16) is set on the 1 MHz or 5 MHz checkpoint nearest the frequency to be used.

e. Adjust XTAL CAL GAIN control (item 21) for a comfortable audio level in headphones.

f. Slowly rotate frequency control around the selected checkpoint until a null (zero beat) is reached.

g. Rotate Cursor Knob (item 3) until cursor is aligned on MEGACYCLES dial with zero-beat point achieved in step f.

h. Rotate frequency control until selected frequency on MEGACYCLES dial appears directly under cursor.

i. Set XTAL CAL switch to OFF.

A FINE FREQ control (item 7) is located on the instrument front panel for making minor frequency adjustments. During normal operation no adjustment of the FINE FREQ control is required, and the knob arrow should be aligned with the front-panel marker. For a precision frequency selection using a frequency counter, the FINE FREQ control is used after the frequency has been selected by use of the frequency control. Turning the knob arrow counterclockwise from the panel marker lowers the frequency, while a clockwise rotation raises the frequency.

Power Output Calibration. The RF leveling circuit in the instrument maintains a flat RF output over wide frequency ranges with proper initial adjustments. These adjustments are conducted using the RF OUTPUT and AMPL

TRIMMER controls in conjunction with the RF OUTPUT meter. The take-off point for the detected RF signal displayed on the RF OUTPUT meter is at the input circuit of the attenuator. Therefore, calibrating the RF output into the attenuator ensures that subsequent operation of the attenuator control will produce an accurate calibrated RF output from the attenuator. RF output calibration procedures are as follows:

- a. Perform turn-on procedures.
- b. Set the MODULATION switch (item 20) to the CW position.

NOTE: For maximum accuracy, power output calibrations should be conducted with the instrument set in the CW mode.

- c. Set the FREQUENCY RANGE switch (item 8) to the desired range.

- d. Tune the frequency control (item 18) five turns in from the low end of the selected frequency range as indicated on the MEGACYCLES dial (item 16).

- e. Adjust the RF OUTPUT control (item 5) for an indication on the RF OUTPUT meter (item 17).

- f. Depress the AMPL TRIMMER control (item 19) and tune for a peak RF indication on the RF OUTPUT meter.

- g. Readjust the RF OUTPUT control until the RF OUTPUT meter pointer is aligned with the +7 dBm (ATTENUATOR CALIBRATED) mark.

NOTE: To calibrate range "E" tune to top of band and repeat steps e through g, before proceeding on to step h.

- h. Tune the frequency control across the selected frequency range. The RF OUTPUT meter pointer should remain aligned with the ATTENUATOR CALIBRATED mark.

NOTE: If the pointer does not remain aligned with the ATTENUATOR CALIBRATED mark, the leveling circuit is not functioning properly. Stop tuning and readjust the AMPL TRIMMER control to restore leveling. The latter adjustment is made without depressing the control.

- i. Proceed with normal operations.

Make special note of the "caution" notes throughout the preceding steps. Remember that you are working with RF and dangers exist.

Exercises (063):

1. Which signal generators (608E or 608F) would you need to produce a 0.7 volt RF signal at 400 MHz?
2. Which control would be used to adjust the percentage of modulation of the RF output signal as observed on the PERCENT MODULATION meter?
3. What indicator shows the selected frequency range and frequency in MHz?

064. State the function(s) of selected controls and settings of a Model 8616A Signal Generator.

Model 8616A Signal Generator. Here is another signal generator, but this one operates in the 1800 to 4500 MHz range. The instrument produces an RF power output of at least 2 mW. Output frequency and attenuation are read directly on digital readouts, and fine frequency changes can be made by means of the front-panel ΔF control.

The instrument has two power output connectors which supply RF power simultaneously. One output provides at least 10 mW (2 mW from 3000 to 4500 MHz) of power and may be leveled. When in the leveled output mode of operation and the output is 0 dBm or less, the RF output is held constant across the frequency band without resetting the attenuator or power monitor. The other output connector provides an uncalibrated output of at least 0.5 mW. A wave-guide-beyond-cutoff attenuator, which is referenced to the RF output, accurately attenuates the calibrated RF power output from 0 to -127 dBm.

RF power output can be internally square-wave modulated. In addition, the RF power can be externally AM, FM, or pulse modulated. An external ALC (automatic level control) input can be used for remote leveling loop control. Also provided is an external DC-coupled FM input which can be used for external AFC.

PIN diode attenuators are used for leveling, square-wave, pulse, and amplitude modulation. The PIN attenuator is an absorption device that can be electrically controlled to attenuate RF power. A sampling loop which includes a PIN diode attenuator compensates for changes in RF power output to hold the RF power output nearly constant.

Two instruments capable of extending the operating parameters of the generator are the 8403A and the Model 2650A. The Model 8403A Modulator produces output pulses with 30 to 40 nanosecond rise and decay time characteristics. Pulse outputs are accurately variable in frequency, width, and delay. Amplitude modulation is available with frequency responses to 10 MHz for sine waves. Square-wave frequency capability is accurately available. The modulator also provides sync and delayed-sync outputs.

The Model 2650A Oscillator Synchronizer may be used directly to stabilize all internal cavity reflex klystron signal generators. Short-term stability is one part in 10^9 /sec, and long-term stability is one part in 10^6 /week over 0 to 50 degrees centigrade.

The Model 8161A can provide 1.0 mW of leveled power across its frequency range (RF outputs leveled to within ± 1.0 dB can be obtained across the band for attenuator setting of 0 dB or less). Output power can be attenuated to -127 dB. When operating unleveled, attenuation reference is the klystron power output; when operating leveled, attenuation reference is output reference setting. Internal square-wave modulation is available from 950 to 1050 Hz. External FM, AM, and pulse modulation voltages also can be used. Two or three modulation modes of operation can be applied to the instrument simultaneously; push-button controls select the mode of operation. External modulation signal inputs are located directly below the modulation to which they apply.

CAUTION: RF power in excess of approximately 125

mW should never be applied to RF power output connectors as internal damage could result.

The front and rear panel controls and connectors are shown in Figure 6-28. Each control and connector is identified by name. The following functions tell what each control or connector does.

a. LINE. This button connects primary power to the instrument. Lamp inside glows.

b. RF. This button applies power to RF POWER outputs.

c. ATTENUATION (dB). This meter and adjustable knob, in the upper right corner of front panel sets and monitors the RF power level at the CAL RF POWER OUTPUT.

d. UNCAL RF POWER OUTPUT. This output, lower right of front panel, provides approximately 0.5 mW unlevelled and unattenuated RF power.

e. FREQUENCY (MHz). This control and meter in the

upper left corner of the front panel, sets and monitors the RF frequency.

f. ΔF . This control, near the middle of the front panel, permits small deviations from FREQUENCY setting (± 1.5 MHz).

g. ZERO SET. This screwdriver adjustment (center of front panel) adjusts for zero indication on dBm meter (with RF turned off).

h. ALC. This control (center of front panel) levels the calibrated RF output (monitored on dBm meter at top center of front panel); use to set a reference on dBm meter.

i. INTERNAL SQ WAVE. This button (center left of front panel) causes modulation of CAL RF OUTPUT. The SQ WAVE control adjusts modulation of frequency.

j. EXTERNAL PULSE. This button and its respective jack directly below it, provides positive pulses that will provide modulation voltages required to pulse modulate the CAL RF OUTPUT. Positive pulses turn RF on.

MODEL 8616A

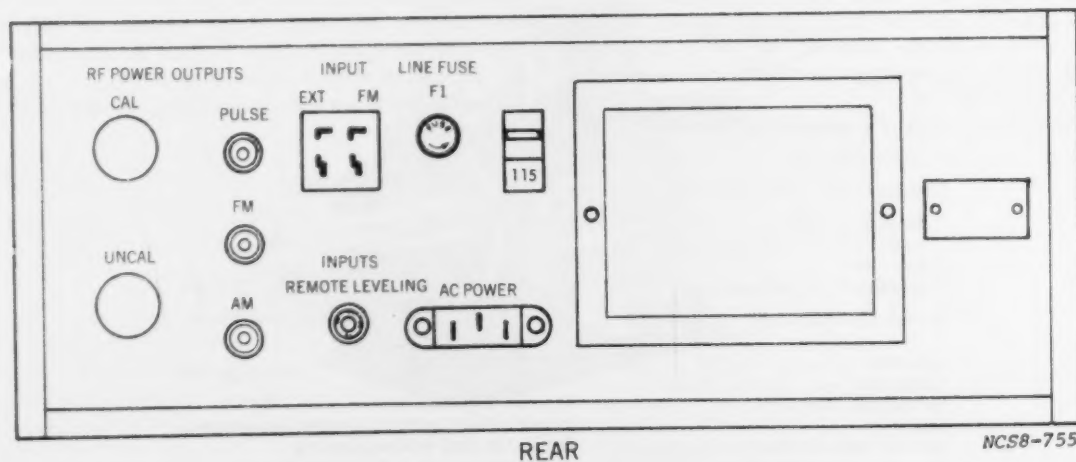
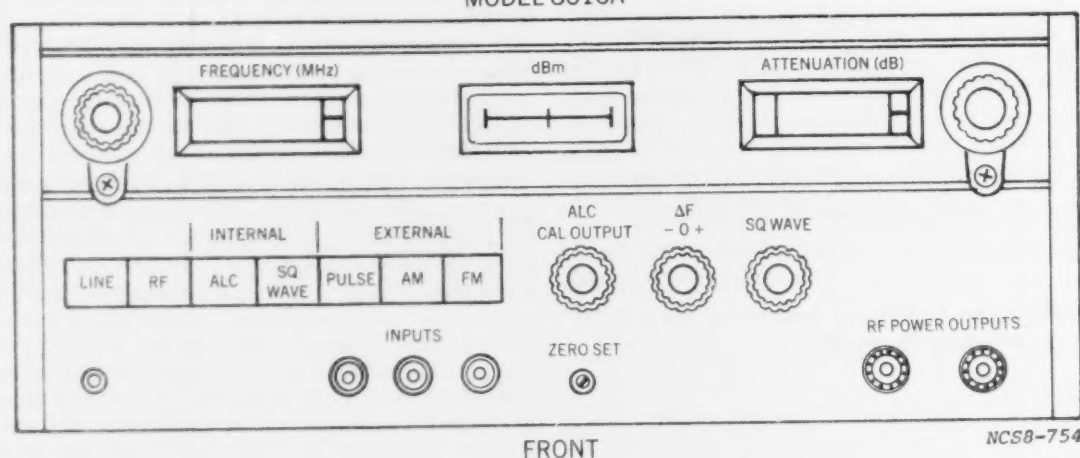


Figure 6-28. Model 8616A Signal Generator front and rear controls and indicators.

k. **EXTERNAL FM.** This button and its respective input jack, directly below, provide AC (FM) voltages that will provide frequency modulation to both the CAL and UNCAL outputs.

l. **EXTERNAL AM.** This button and its respective input jack, directly below, provide AM input voltages that will provide modulation voltages required to AM modulate the CAL RF OUTPUT.

m. **INPUT REMOTE LEVELING.** This input jack, located on the rear panel, is for external leveling loop voltage which is applied to level generator CAL RF POWER OUTPUT.

n. **LINE.** This male receptacle, on the rear panel, connects to the AC power cord.

o. **LINE VOLTAGE.** This device, located on the back panel to the right of the line fuse, F1, arranges the input power transformer to accept either 115 or 230 volt, 50 to 60 Hz primary power input.

Exercises (064):

1. Which control on a Model 8616A signal generator permits small deviations to be made to the FREQUENCY setting?
2. Which meter on a Mode 8616A signal generator allows the operator to observe the RF frequency?
3. Which control allows the operator to select 115V versus 230V input line power?

065. State the function(s) of selected controls and settings of a TS-270 Echo Box.

TS-270 Echo Box. There are several models of the TS-270 echo box, and they're all almost identical. In this section we'll cover the controls, etc. of a basic unit although the one you have may be slightly different. We'll refer to it as the TS-270.

The TS-270 echo box is a portable test unit designed for

performance testing of radar sets operating in the 2,700- to 2,900-mc (megacycle) band. When properly used, it will detect and locate incorrect adjustments or defects in the radar set. In this way, the echo box helps maintain radar set operation at good efficiency by indicating poor performance so that repairs or readjustments can be made. The echo box supplements, but does not replace, other and more elaborate radar test equipment and facilities. Some of the more important uses of Echo Box TS-270 (*)/UP are as follows:

- (1) Overall performance check of radar (ringtime).
- (2) Analysis of transmitter frequency spectrum.
- (3) Measurement of pulse duration.
- (4) Relative indication of transmitter power output.
- (5) Tuning of radar equipment.
- (6) Measurement of transmitter frequency.
- (7) Measurement of receiver local-oscillator frequency.
- (8) Checking erratic transmitter operation.
- (9) Check of transmitter frequency pulling.
- (10) Check of receiver AFC (automatic frequency control).
- (11) Measurement of TR (transmit/receive) box recovery time.
- (12) Measurement of receiver recovery.
- (13) Check of transmission line loss.
- (14) Guide for trouble location.

Basically, the echo box is a cylindrical resonant cavity with a movable plunger (as we covered back in Section 6-1). The echo box is hand-tuned by moving the plunger within the cavity. Connection to a radar set is made through a directional coupler (built into the transmission line of the radar set) or by a small pick-up antenna placed in the RF (radio frequency) beam of the radar set. A portion of RF energy from a radar set causes oscillations to build up in the resonant cavity of the echo box when the cavity is tuned to the frequency of the pulse. The oscillations will continue after the radar pulse but will gradually die out, because some of the energy is radiated back to the radar set and more energy is dissipated in the cavity and output meter circuit. The energy which is coupled back to the radar set is detected by the radar receiver and observed on the radar oscilloscopes. The length of time between the start of the transmitter pulse and the point at which the oscillations fade into the receiver noise is called the ringtime.

The following list has the technical characteristics of a TS-270 echo box.

Frequency range	
Nominal	2,700 to 2,900 mc.
Actual	2,630 to 2,970 mc.
Tuning control	Hand-operated dial.
Ringtime	Depends on the radar set used and the test conditions.
Methods of coupling radar set	By directional coupler or pick-up dipole antenna (or coaxial horn).
Input loop	Coupling position fixed.
Output loop	Coupling position variable.
For use with scopes type	A, J, PPI, and others.
Sensitivity	90 yards per db (decibel) on ringtime measurement.
Ringtime calibration factor	Stamped on meter window in percent.
For testing pulsed radar types	All in frequency range of 2,700 to 2,900 mc.
Power level and resonance indicator	0- to 100-microampere meter.
Crystal type	1N21B.

Figure 6-29 gives you an idea of what an echo box looks like and where some of the devices and controls are located.

Exercises (065):

1. Where does a TS-270 echo box obtain or sample a radar's transmitted RF energy?
2. Where would you normally find the "calibration factor" of an echo box?

066. Identify given HP-432A power meter control functions.

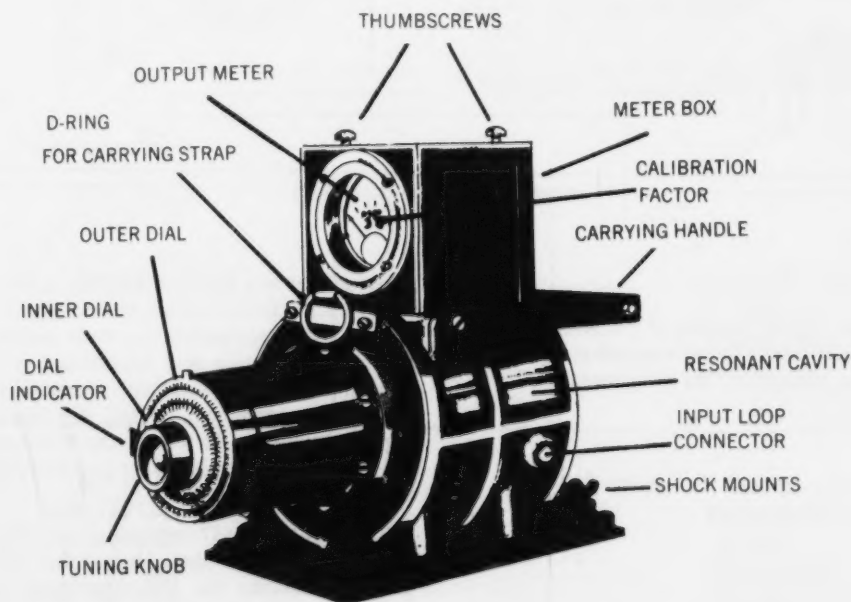
HP-432A Power Meter. The Hewlett-Packard (HP) 432A power meter is the meter most widely used in our career field for making power measurements. The reason is that when it is properly calibrated it can be used to measure the proper outputs of each type of radar transmitter we use. The HP-432A power meter uses a thermistor bridge network and requires the use of a thermistor mount to complete the circuit. The thermistor mount is connected between the meter and the RF input to the meter.

Temperature stability is critical for the proper operation of the HP-432A and it should be allowed to warm up for approximately 10 minutes before use. The thermistor

mount is also a temperature sensitive device and care should be taken not to hold it in your hand.

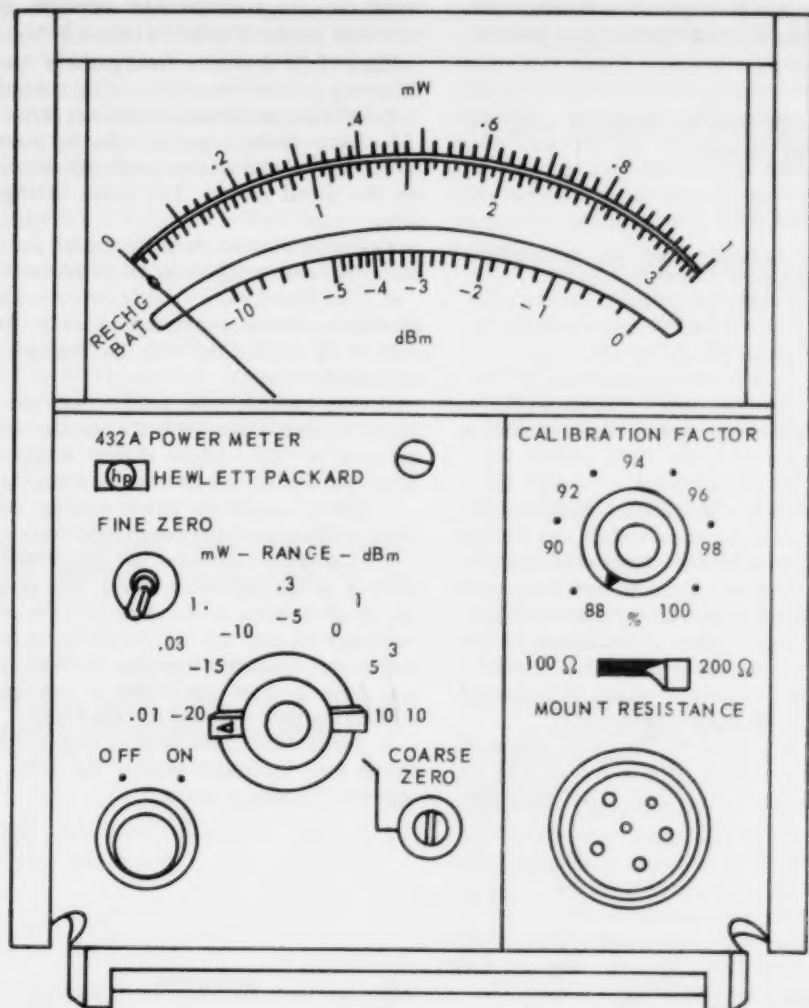
Figure 6-30 shows the front panel of the HP-432A. The following is a brief description of the controls and their use.

- a. Off/On - pushbutton switch that glows when it is on.
- b. Range Switch - used to select the power measurement range. Range settings are used with the meter readings to get the actual power. The inside settings are shown in dBm.
- c. Course Zero - with no RF applied and the range switch set to course zero, adjust for the proper indication.
- d. Fine Zero Switch - toggle switch to electronically fine zero the thermistor compensation bridge. It should be used with no RF applied and with the range switch on the range to be used.
- e. Mechanical Meter Zero - with no power applied, adjust it clockwise until the needle drops below and balances at zero. Adjust slightly counterclockwise after zeroing to free the needle from the adjusting mechanism.
- f. Meter - to get the power reading, subtract the meter reading (dBm) from the value of the range switch position.
- g. Calibration Factor - set the switch to the reading marked on the thermistor mount. The purpose is to match the characteristics of the mount to the meter. It may be necessary to reset the calibration factor for each different transmitted frequency (because of SWR) you check, or you may have to leave the switch in one position and use a conversion chart provided by your PMEL.
- h. Mount Resistance Switch - to be left in one position to match your thermistor mount. The 478A (most common) uses the 200-ohm position.



NGE13-95A

Figure 6-29. TS-270 Echo Box.



NCS18-599A

Figure 6-30. HP-432A Power Meter.

Exercises (066):

1. The 432A has a meter reading of -6 with the range switch set to zero and external attenuation equal to 45 db. What is the amount of dBm being measured?
2. What conditions should be established prior to "zeroing" the power meter?

067. Identify the purpose of selected modules contained in an AN/UPM-137 Radar Test Set.

AN/UPM-137 Radar Test Set. The AN/UPM-137

radar test set is a very valuable aid in the maintenance of identification friend or foe (IFF) or selective identification feature (SIF) equipment. A basic understanding of its functional operation and capabilities will assist you in performing the checks and alignments required to keep the interrogator equipment on the air. Since you are only required to operate the test set, our discussion includes only the front panel controls and the input/output signals that are used to perform your tests.

The AN/UPM-137 test set is actually four test sets combined into one case. Use of this unit is required to properly maintain the IFF interrogator and transponder equipment. The AN/UPM-137 is a specialized piece of test equipment with the versatility of providing any signal or combination of signals that will allow you to accurately check the performance of a large part of the IFF system, including the following components:

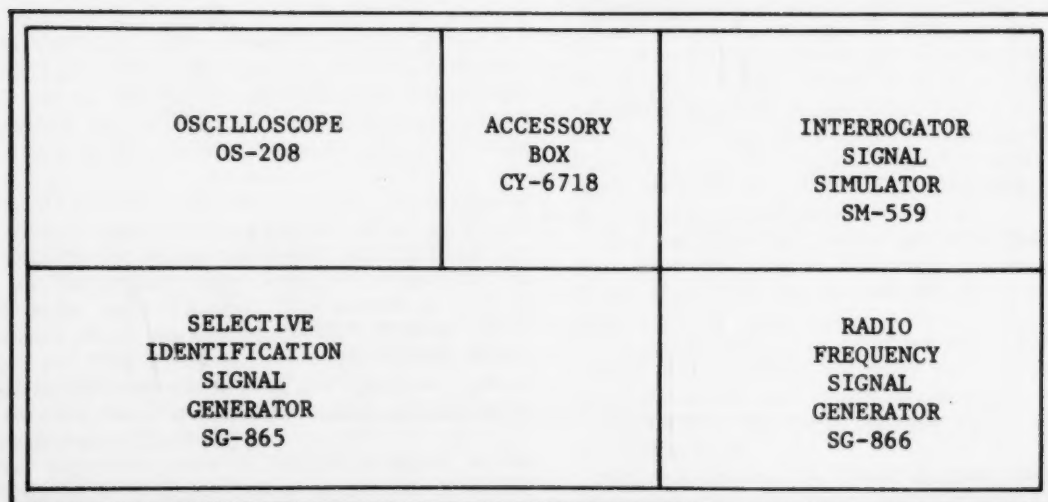
- Receiver/transmitter unit.
- Interference blanker.
- Antenna switch control.
- Signal processor.
- Video signal processor.

The AN/UPM-137 consists of four separate modules powered by a common internal power supply. The modules may be used independently or in conjunction with each other and are arranged as shown in figure 6-31.

The oscilloscope (OS-208/UPM-137) is located in the top left corner of the case, and it provides all of the features required for measuring the pulse and signal characteristics of the test set and the IFF equipment. Immediately to the right of the oscilloscope is the interrogator signal simulator (SM-559/UPM-137). This unit provides RF signals for radar video simulation and active readout signals for testing radar display systems. The selective identification signal (SIS) generator (SG-865/UPM-137) is located in the lower left corner. The SIS generator is used to produce test SIF pulse trains, triggers, and pulses for testing and aligning the SIF interrogator, transponder, and display system equipment. Just to the right of the SIS generator is the radio frequency (RF) signal generator (SG-866/UPM-137). This module generates, mixes, and demodulates the RF signals required to check the interrogator transmitter and receiver. Located between the oscilloscope and interrogator signal simulator modules is an accessory box that is used for storing all accessories used with the test set.

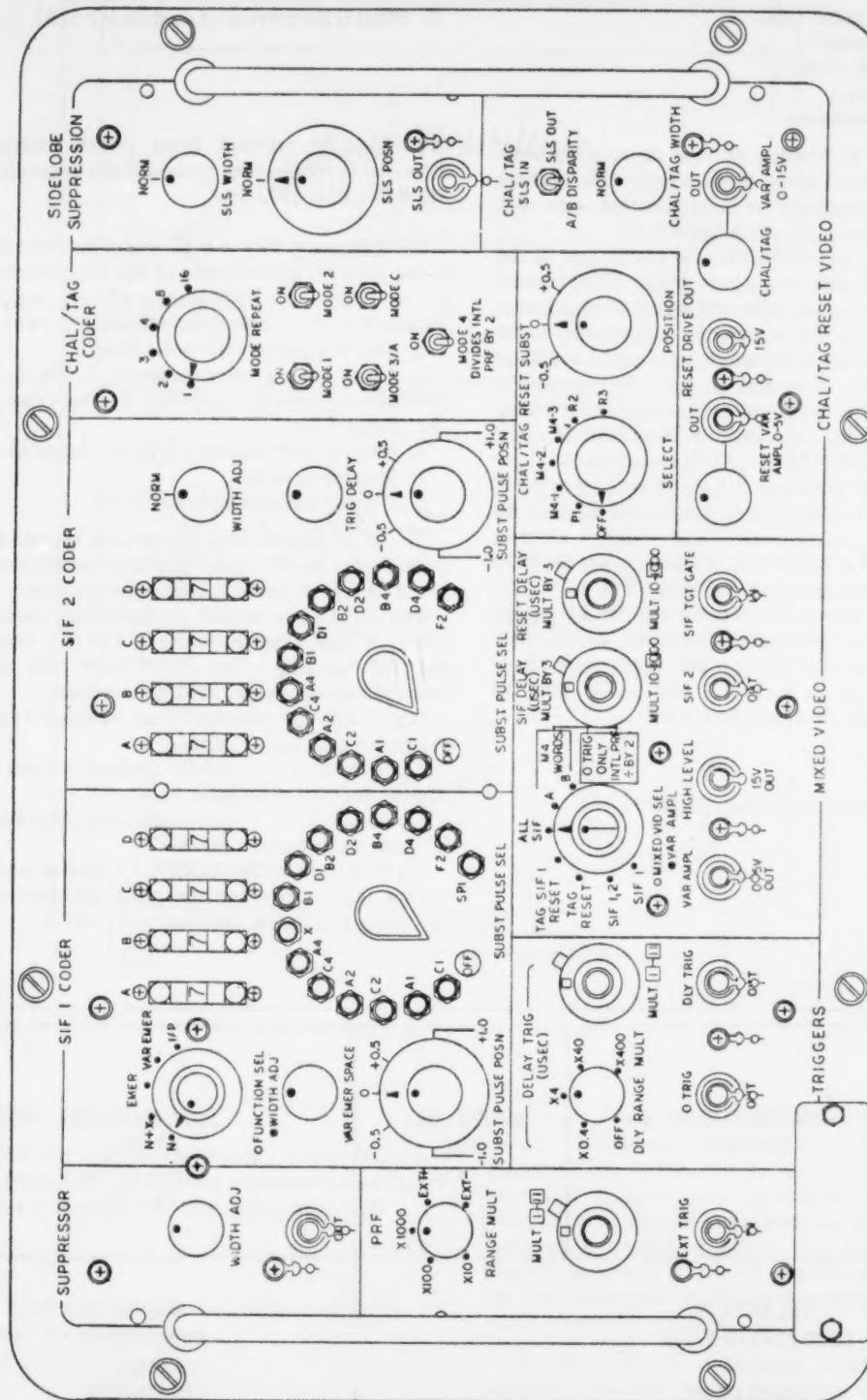
Exercises (067):

1. What is the purpose of module SG-866?
 2. What is the purpose of module SG-865?
- 068. Identify selected front panel controls of the Selective Identification System (SIS) generator module, SG-865/UPM-137.**
- SIS generator.** Figure 6-32 shows the front panel layout of the controls and switches of the SIS generator. As you can see, there are a large number of them, and they are all necessary to provide the following IFF test video.
- a. Two independent SIF pulse trains.
 - b. Challenge/tag video (modes 1, 2, 3A, 4, and C) and side-lobe suppression (SLS) challenge/tag video.
 - c. Reset video.
 - d. Word A or B (mode-4), with or without SLS pulses.
 - e. Suppressor pulse.
 - f. Triggers (delayed and undelayed).
- The video outputs from this unit can be used to modulate the RF from the RF signal generator for receiver checks or as raw video for checking the display systems.
- The SIF 1 pulse train is produced and controlled at the SIF 1 CODER when the MIXED VID SEL switch is set at any SIF position. The FUNCTION SEL switch will establish any one of five pulse train formats.
- (1) NORMAL - includes F1 and F2 bracket pulses and 12 selectable information pulses.
 - (2) NORMAL + X (N+X) - includes a fixed pulse in the X pulse position of the pulse train.
 - (3) EMERGENCY - includes normal pulse train followed by three sets of bracket pulses.
 - (4) VARIABLE EMERGENCY - same as preceding train except spacing between the pulse train and each set of bracket pulses can be simultaneously varied.



NCS18-559

Figure 6-31. AN/UPM-137 Radar Test Set module location.



NCS18-550

Figure 6-32. SIS generator module front panel layout.

(5) IDENTIFICATION POSITION (I/P) - includes a normal train followed by a special position identifier (SPI) pulse.

All pulses except the F pulse in the train can be substituted with a variable substitution pulse. The pulse widths are simultaneously adjusted with the WIDTH ADJ control. This control should be kept as far CCW as the test procedures allow to prevent severe distortion of the pulse train. The SIF 1 pulse trains are available at the MIXED VIDEO VAR AMPL 0-5V OUT and HIGH-LEVEL 15V OUT jacks. It should be noted here that a SIF 2 train is available at the SIF 2 OUT jack during any SIF 1 train operation.

Both SIF 1 and SIF 2 pulse trains are available at the mixed video output jacks in the SIF 1, SIF 2, or ALL SIF positions of the MIXED VIDEO SEL switch. The SIF 2 trains are controlled by the SIF 2 CODER and do not contain the X pulse, emergency train, or I/P option. The delay between the SIF 1 and SIF 2 trains may be varied with the TRIG DELAY control until they are interleaved or completely separated. A 4.35-microsecond spacing between the two can be used to obtain a mode 2 emergency train.

The challenge tag and reset generators produce challenge/tag and reset signals with variable spacings. These signals can be used to check out the standby transmitter/receiver unit without using the triggers from operational unit. Challenge/tag includes modes 1, 2, 3A, C, and 4 in interlaced and repeated modes, with or without side-lobe suppression (SLS). Each individual MODE switch placed in the ON position will cause its P1 pulse to appear in the signal. The selected modes can be repeated 1, 2, 3, 4, 8, or 16 times, depending on the setting of the MODE REPEAT switch. The modes are placed in numerical sequence (111222333 for count 3) and are skipped if not selected. The challenge/tag output is continuous, repeating the numerical sequence selected. The P1 pulse may be substituted with the CHAL/TAG RESET SUBST SELECT switch and POSITION control. A challenge/tag SLS pulse can be introduced with the CHAL/TAG SLS A/B DISPARITY switch by placing it in the SLIS IN position. The position and width of the SLS pulse can be adjusted by the controls in the side-lobe suppression section of the panel. Challenge/tag and SLS video are available at their individual output jacks and at the mixed video outputs.

The SIS generator may be triggered internally or by using a positive or negative external trigger source. Two triggers are available for synchronizing other equipment with the test set. The primary trigger is the "0" trigger, and the other is the delayed trigger. The amount of delay is dependent on the position of the DLY RANGE MULT switch and MULT control. The DLY RANGE MULT switch should be initially set to the X400 position. If you do not have this control in the X400 position, you may not be able to obtain a video display.

The suppressor pulse is always available at the SUPPRESSOR OUT jack and is independent of all SIF CODER functions. Its duration is set with the WIDTH ADJ control. This pulse is used to test the receiver suppressor circuits of the IFF equipment.

Exercises (068):

1. What pulse train format will be established if the FUNCTION SEL switch is placed to NORMAL + X (N+X) position?
2. Which control sets the duration time of the suppressor pulse available at the SUPPRESSOR OUT jack?

069. Identify characteristics of selected output signals of the interrogator signal simulator module, SM-559/UPM-137.

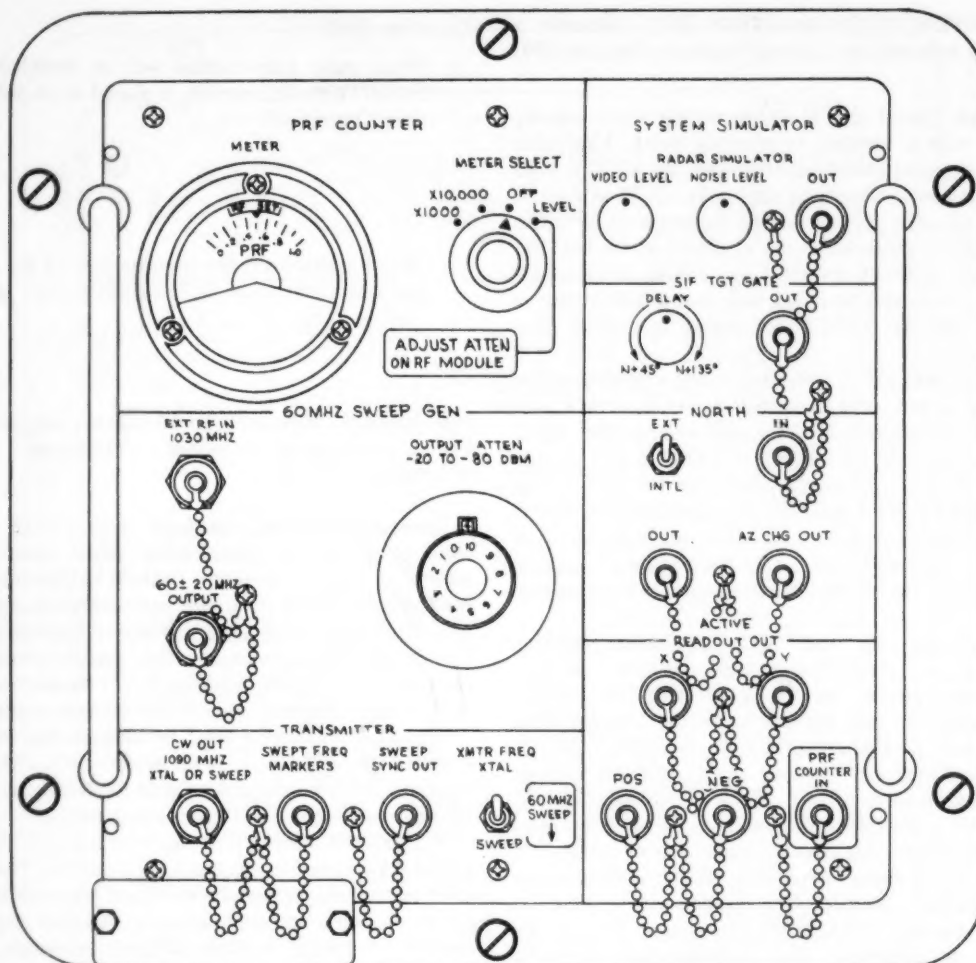
Interrogator signal simulator. Figure 6-33 shows the front panel of the interrogator signal simulator. The interrogator signal simulator (SM-559/UPM-137) module produces RF signals for transmitter/receiver test procedures and radar video simulation and active readout signals for testing radar display systems. This module consists of four sections: (1) a system simulator, (2) transmitter, (3) 60-MHz sweep generator, and (4) PRF counter section.

The PRF counter is used to indicate the PRF of the system under test. The LEVEL position of the Meter Select switch is used in conjunction with the RF signal generator module to calibrate the 60-MHz signal output.

A fixed 1,090-MHz CW signal or a 1,070-MHz sweep signal is generated in the transmitter section. These signals must be coupled through the RF signal generator module for RF level control and demodulation. Another output of this section is frequency markers. These markers are used with the 60-MHz sweep frequency signal and represent the center frequency and the ± 3 , ± 5 , ± 10 , and ± 20 MHz points. The sweep sync out jack provides a signal that can be used to synchronize the oscilloscope with the sweep signal. Notice that the XMTR FREQ switch is labeled XTAL and SWEEP with a placard to the right denoting that the 60-MHz SWEEP position is the down position. This position of the switch is used for the 1,070-1,110 MHz and the 60-MHz sweep signals. To obtain the 60-MHz sweep signal, you must connect the 1,030-MHz output of the RF signal generator to the EXT RF IN 1,030 MHz jack in the 60-MHz sweep generator section.

The system simulator section produces three simulated radar video pulses having different widths and amplitude. These pulses can be provided with or without noise and are used to test the radar display video circuits. The video levels are simultaneously controlled with the video level control. The amplitude and noise levels are adjusted to establish various video input conditions for the display system circuits. The output for these signals is the radar simulator out jack.

Also available from the system simulator section are the active readout signals. These signals represent a target area approximately 15 miles within a 3° to 10° sector. Antenna azimuth rotation data (ACPs and ARPs) simulating an



NCS18-552

Figure 6-33. Interrogator signal simulator front panel layout.

antenna rotation speed of 6 rpm are generated for the active readouts. The SIF TGT GATE OUT jack should be connected to the SIS generator to synchronize its SIF pulse train within the target area.

Exercises (069):

1. What signals are available from the transmitter section of the interrogator signal simulator?
2. What type of signals are produced in the radar simulator section of the system simulator?

3. Describe the output of the 60-MHz sweep generator section of the interrogator simulator.

070. State the purpose of the RF signal generator module, SG-866/UPM-137.

RF signal generator. The RF signal generator (SG-866/UPM-137) generates, mixes, demodulates, and controls the RF levels of the signals required to test and align the interrogator transmitter and receiver. The attenuation controls are used to control the RF level of the signals produced by the module and the level of the RF applied from other sources. As you can see in figure 6-34, this module is divided into three sections: (1) video, (2) transmitter, and (3) RF.

All of the signals demodulated by the RF signal generator are available at the VIDEO OUT jack of the video section. Two modulation inputs, auxiliary and main, are provided to produce RF pulses at two separate levels. The AUX ATTEN control is used to control the RF level of the auxiliary RF path, and the OUTPUT ATTEN control sets the level of the RF in the main RF path. By connecting the MOD OVERRIDE (CW) jack to either modulation input, a CW RF signal is produced at the SIG GEN RF IN/OUT jack.

The transmitter section provides a 1,030-MHz crystal-controlled frequency or a 1,010–1,050-MHz sweep frequency, depending on the position of the XMTR FREQ switch. These signals are available at the RF SIG GEN IN/OUT jack. The CW SOURCE switch is used to enable the external 1,090-MHz signal from the interrogator signal simulator to be routed through the RF signal generator for RF level control. The sweep-frequency marker and sweep-synch output signals are identical to the signals described in the interrogator signal simulator. The output of the FREQ PROBE jack is the result of heterodyning the RF input under test with one of the radar test set RF sweep signals. This output will provide you with a video signal during transmitter frequency checks.

In the RF section, the POWER PROBE RF IN/OUT jack is used for connecting the interrogator transmitter output directly to this module. Depending on the power level input, the HIGH or LOW POWER PROBE jack is then connected to the SIG GEN IN/OUT jack. If the power-level inputs are 50W or less, it can be connected directly to the SIG GEN IN/OUT jack. The RSLS (receiver side-lobe suppression)-17 dB jack provides RF that is attenuated with

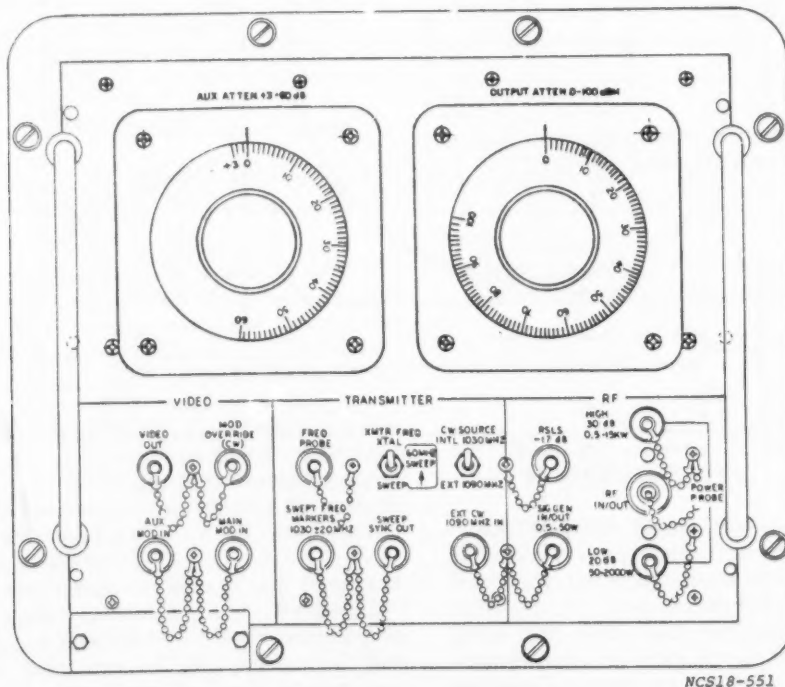
respect to the auxiliary RF path. This output is used as the difference antenna input for SLS checks.

Exercises (070):

1. List the five signals available from the transmitter section of the RF signal generator module.
2. What is the purpose of the RF signal generator module?

071. Describe the methods used to add frequency markers to the A and B sweeps of the oscilloscope module of an AN/UPM-137 radar test set.

Oscilloscope. With the built-in oscilloscope (OS-203/UPM-137), it is not necessary for you to set up an additional piece of test equipment to perform your checks and alignments of the IFF equipment. This module provides all of the features required for measuring the pulse and signal characteristics of the test set and interrogator equipment. Figure 6-35 shows the front panel layout of the oscilloscope, and, as you can see, it contains the same controls found on most dual-trace scopes. An added feature of this unit, however, is the internally generated frequency markers that can be added to the B channel sweep. The XTAL MARK (USEC) switch in the lower right corner



NCS18-551

Figure 6-34. RF signal generator front panel layout.

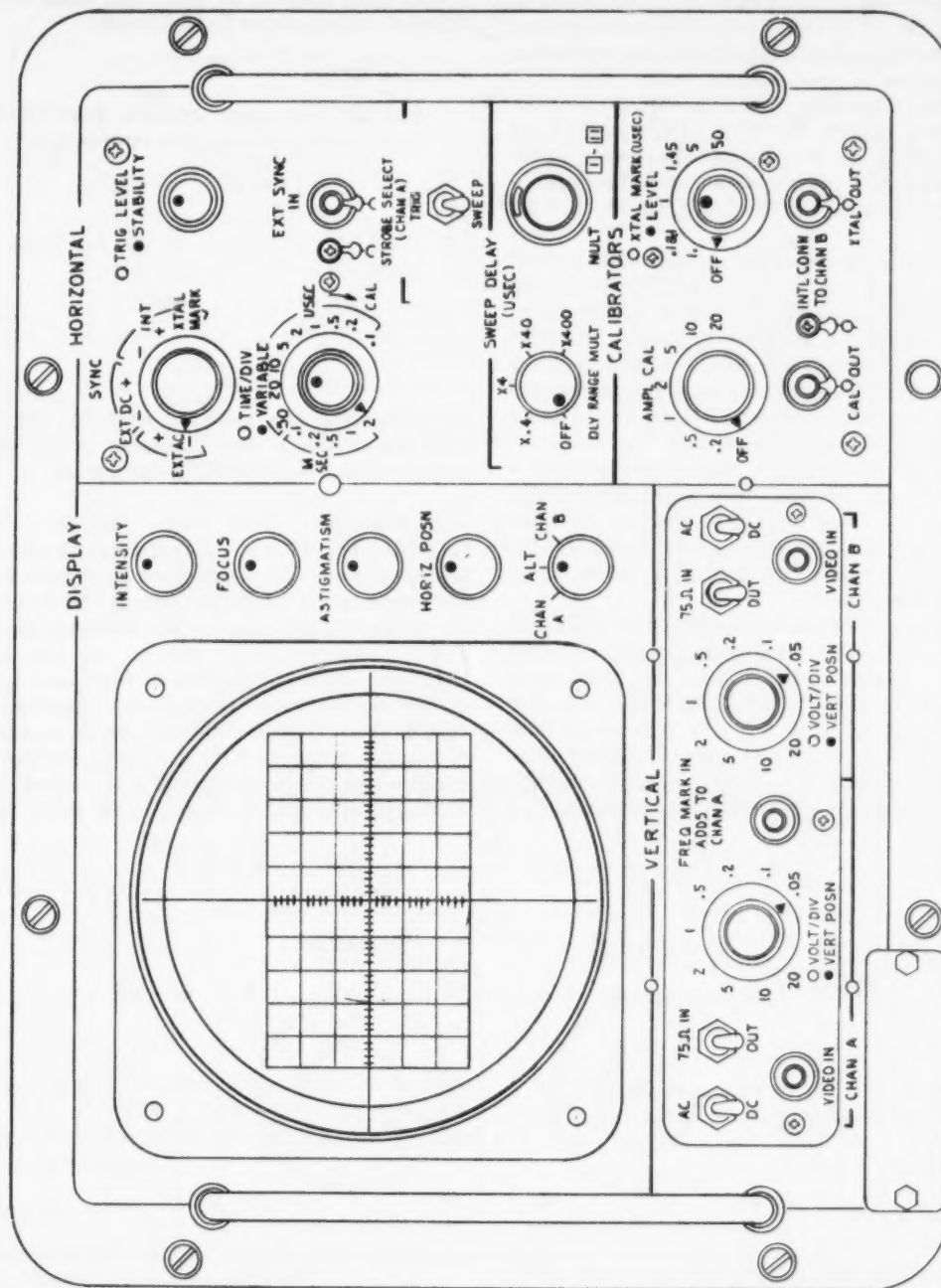


Figure 6-35. Oscilloscope module front panel layout.

NCS18-553

allows you to add the desired frequency markers to the B channel sweep. Also, frequency markers from either the interrogator signal simulator or the RF signal generator may be added to the A channel sweep. These markers are applied to the FREQ MARK IN jack located in the center of the vertical section of the scope.

Exercises (071):

1. How are frequency markers added to the B channel sweep?
2. Where are the frequency markers from the RF signal generator applied to add them to the A channel sweep?

072. Identify the operating procedures for the AN/UPM-137 radar test set.

AN/UPM-137 operating procedures. Due to the many signals required to perform some of the maintenance checks with the AN/UPM-137, you may find yourself tangled in RF video cables if you are not careful. Here are a few rules you should follow to prevent that from happening and to simplify your operation of the test set.

- (1) Never connect a short cable to the AN/UPM-137; otherwise, the test set may be changed.
- (2) Doublecheck your connections to be sure you are not connecting to the wrong jack.
- (3) Use test cables of sufficient length to make your connections; too long is just as bad as too short.
- (4) Keep the cables, connectors, and probes off the floor. In addition to getting stepped on, they could also cause someone to trip and fall.
- (5) Store the test cables and probes in the accessory case provided.
- (6) Treat the test cables with the same care that is required for the test set. After all, they are part of the test equipment.

As you have probably already discovered, it can be very frustrating to finish a test procedure hook-up and not be able to complete the entire procedure because of defective test cables or malfunctioning test equipment. By following the rules above and by taking proper care of the test equipment you will not make your job more complicated than it is.

Prior to using the AN/UPM-137, it is necessary to set the controls and switches to certain specified positions. If this is not done, you may have difficulty in achieving the proper results from the test procedure. The following list gives the required control positions for what we call "normalizing" the controls of the AN/UPM-137.

As with any new system or piece of test equipment, proficiency is attained only through practice. By applying a reasonable amount of attention to detail and analyzing the purpose behind each step of the procedures, your proficiency with the AN/UPM-137 should increase each time you use it. By following the procedures as they are

listed in the technical orders (TOs), you should not have any difficulty in becoming proficient with this test set.

WIDTH ADJUST	fully CCW
PRF	EXT +
MULT 1-11	fully CCW
FUNCTION SEL	N
WIDTH ADJ	fully CCW
VAR EMER SPACE	Midrange
SUBST PULSE POSN	0
SUBST PULSE SEL	Off
SIF 2 WIDTH ADJ	NORM
SIF 2 TRIG DELAY	fully CW
DELAY RANGE MULT	X400
(DELAY TRIG) MULT 1-11	fully CCW
MIXED VIDEO SEL	SIF 1
VAR AMPL	fully CW
SIF DELAY MULT BY 3 10-1000	fully CCW
RESET DELAY MULT 10-1000	fully CW
MODE REPEAT	1
MODE 1	Off
MODE 2	Off
MODE 3	Off
MODE C	Off
MODE 4	Off
CHAL/TAG SELECT	Off
CHAL/TAG POSITION	0
RESET VAR AMPL 0-5	fully CCW
SLS WIDTH	NORM
SLS POSN	NORM
SLIS IN/OUT	OUT
CHAL/TAG WIDTH	NORM
CHAL/TAG VAR AMPL	fully CCW
	INTERROGATOR SIGNAL SIMULATOR
METER SELECT	OFF
XMTR FREQ	XTAL
	RF SIGNAL GENERATOR
AUX ATTEN	0
OUTPUT ATTEN	0
XMTR FREQ	XTAL
CW SOURCE	INTL 1,030 MHz

Exercises (072):

1. List three precautions that should be taken when the AN/UPM-137 is being connected for a test procedure.
2. Why should you follow the procedure for normalizing the controls of the AN/UPM-137?

073. State the purpose of selected controls of the AN/UPM-145 Radar Test Set.

AN/UPM-145 Radar Test Set. The AN/UPM-145 radar test set is a portable, X-band transponder/analyzer. It is used to test and adjust pulse radar, CW radar, and beacon radar systems. The test set replaces the much maligned UPM-10B. Since tests are initiated and controlled by controls provided on the test set front panel, this section is designed to provide you with a working knowledge of these controls.

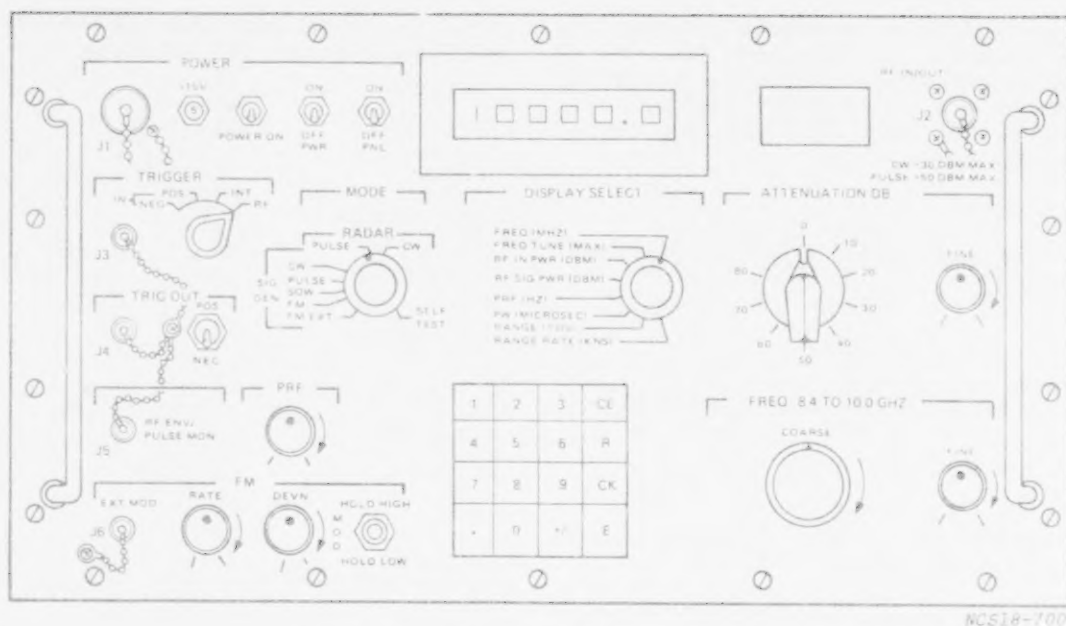


Figure 6-36. AN/UPM-145 Radar Test Set front panel controls.

Function. The planned purpose of the AN/UPM-145 is to test X-band radar power, frequency, pulse repetition frequency (PRF), radar-tracking capabilities, and receiver bandwidth and minimum discernable signal. The set can also be used as a signal generator with continuous wave (CW), pulse modulated (PULSE), square wave (SQW), or frequency modulated (FM) outputs. These generated signals are controlled in frequency, power, PRF, pulse width, range, and range rate.

Controls. In the course of making two tests (transmitter power and receiver sensitivity—perhaps the only routines you will be required to use) certain features will be used, to the exclusion of others. The following narrative will cover only those features you are most likely to use, excluding the more obvious, such as power ON/OFF. The front panel features can be seen in figure 6-36.

RF IN/OUT. RF IN/OUT connector J2 is one of those more obvious items that was to be excluded from this objective. But, there is something you should know about J2. *Damage to the test set may result if maximum input power levels are exceeded.* The maximum peak power that can be applied to the connector is +50 dBm for pulsed radar systems. Insure that attenuation from couplers and cables is enough to reduce these power levels below 50 dBm prior to the test set connection.

Trigger. When performing MDS checks, the four-position trigger select switch providing for selection of test set triggering will be set to the RF position. Unless you use the signal generating mode, you should be able to leave the switch in RF, allowing synchronization of the test set by the leading edge of the pulsed RF input. The other positions allow selection of test set triggering, by either the positive or negative edge of input triggers, or internal triggering by the PRF generator.

Mode. Providing for selection of the UPM-145 mode of operation (radar, signal generation, or self-test), the eight-position rotary MODE switch will normally be in the RADAR-PULSE position.

Display select. The display select switch performs two functions. The more obvious use is to select the parameter to be shown on the six-digit numeric display above the switch. The selectable positions and the parameters displayed are described in the following list.

- (1) FREQ (MHz)—selects direct display of test set oscillator frequency.
- (2) FREQ TUNE (MAX)—selects direct display of test set oscillator frequency to radar input frequency.
- (3) RF IN PWR (dBm)—selects direct display of input peak-power level at connector J2. This position used when measuring transmitter power.
- (4) RF SIG PWR (dBm)—selects direct display of test set output peak power at connector J2. This position is used for measuring MDS.
- (5) PRF (Hz)—selects direct display of radar PRF (TRIGGER switch set to RF), test set internal PRF (TRIGGER switch set to INT), or external trigger PRF (TRIGGER switch set to IN POS or IN NEG).
- (6) PW (MICROSEC)—selects direct display of generated target pulse width. Also enables keyboard entry of new pulse width (MODE switch set to RADAR PULSE or SIG GEN PULSE).
- (7) RANGE (YDS)—selects direct display of test set generated target range. Also enables keyboard entry of new range (MODE switch set to RADAR PULSE or SIG GEN PULSE).
- (8) RANGE RATE (KNS)—selects direct display of test set generated target range rate. Also enables keyboard entry of new range rate (MODE switch set to RADAR PULSE or SIG GEN PULSE). KNS signifies "knots."

The less obvious purpose of the display select switch is to select the keyboard (below the switch) entry mode.

Keyboard. The 16-key keyboard allows you to enter the following parameters, when the MODE switch is set to RADAR PULSE or SIG GEN PULSE modes and the DISPLAY SELECT is in the appropriate position:

a. Pulse width—0.12 to 5.00 microseconds in 0.01-microsecond steps.

b. Range—250 to 40,000 yards in 10-yard steps.

b. Range rate—+2,000 to -2,000 knots in 1-knot steps.

ATTENUATION dB. A functional group is identified by the ATTENUATION dB heading. Included in the attenuation group are a nine-position rotary switch (attenuation of RF IN/OUT signal from 0 to 80 dB in 10-dB steps) and a potentiometer (FINE, providing continuous attenuation adjustment of test set RF output signal level from +7 to -15 dB).

FREQ 8.4 TO 10.0 GHz. Another functional group, the FREQ 8.4 TO 10.0 GHz controls (COARSE rotary control, and FINE control potentiometer) provides continuous frequency adjustment of the test set oscillator. The COARSE control requires 8 turns (CW) to change frequency from 8.4 to 10.0 GHz, returning to 8.4 GHz when tuned past 10.0 GHz. The FINE control has a 10-MHz range within the COARSE frequency setting.

Transmitter power. When measuring pulsed transmitter power, the test set provides peak-power readings, whereas the transmitter power parameter is usually listed as average power. The peak-power reading can be converted to average power by the following equations:

$$\begin{aligned} \text{AVG} &= \text{PEAK} + 10\log(\text{PW}/\text{PRI}) \\ \text{AVG} &= \text{PEAK} + 10\log(\text{PW} \times \text{PRF}) \end{aligned}$$

where:

AVG = average power in dBm
Peak = peak power in dBm
log = base 10 (common) logarithm
PW = pulse width in seconds
PRI = pulse repetition interval in seconds
PRF = pulse repetition frequency in Hertz

Exercises (073):

1. What frequency range is the UPM-145 designed to test?
2. What is the maximum peak-power level that can be applied to the input of the radar test set?
3. When wouldn't the TRIGGER switch be in the RF position?
4. How is the DISPLAY SELECT switch used when measuring power?

074. Identify key features of the TV-7/U Electron Tube Tester.

TV-7/U, Electron Tube Tester. This test set is a portable tester of the dynamic mutual conductance type and is rugged enough for shop and field work. It can measure performance capabilities and determine the rejection limits for the electron tubes used in receivers, low-power transmitters, and many other electronic devices.

Controls. Figure 6-37 shows the TV-7/U test set's front panel. The operating controls are as follows:

a. **POWER switch**—This on-off switch applies primary power to the test set.

b. **LINE ADJUST control**—This controls the input to the power transformer. The LINE ADJ button is depressed and the LINE ADJUST control varied until the meter reads on the indicated line on the meter face.

c. **GRID, PLATE, SCREEN, CATHODE, SUPPRESSOR, and FILAMENT switches**—These rotary selector switches connect the various tube elements to the correct voltages to conduct the desired test. You can determine the position of these switches for a specific tube under test by referring to the information provided in the Tube Test Data Chart.

d. **FILAMENT VOLTAGE switch**—This selector switch provides filament voltages from 0.6 to 117 volts in 18 steps to the specific tube under test. The BLST position is used when you are testing ballast tubes.

e. **BIAS control**—This controls the bias on the tube under test.

f. **SHUNT control**—This controls the sensitivity of the meter circuit when the FUNCTION switch is in the A position.

g. **FUNCTION switch**—This switch selects the proper meter range for the tube under test in positions A through E. In the SHORTS position (1 through 5), the switch connects various elements of the tube under test to the short-indicating circuit.

h. **LINE ADJ button**—You depress this switch to set the AC line adjustment.

i. **MUT COND button**—You depress this switch only when you are checking amplifier tubes.

j. **DIODE button**—This switch is used to check low-power rectifiers similar to those used for second detectors.

k. **GAS 1 and GAS 2 buttons**—You depress these switches to make the gas test.

l. **OZ4 button**—Depress this switch when you are testing cold cathode rectifier tubes, such as type OZ4.

m. **RECT button**—You depress this switch to test the rectifier tubes used in power supplies.

n. **METER REV button**—You depress this button to reverse the polarity of the meter when you are testing certain tubes in accordance with the instructions in the Tube Test Data Chart.

o. **G jack**—This is the tip jack to which the grid caps are connected.

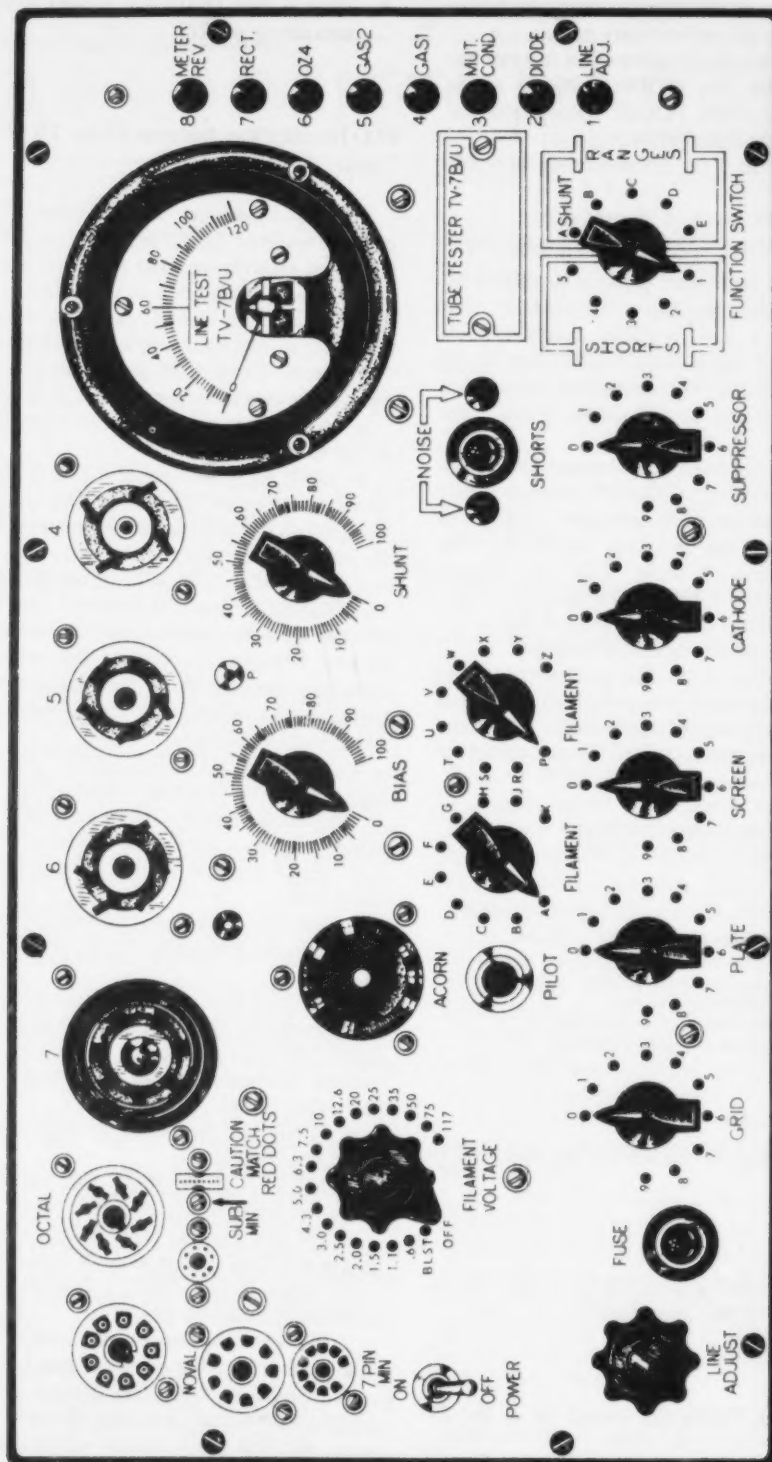


Figure 6-37. TV-7/U Electron Tube Tester.

NGE13-90

p. P jack—This is the tip jack to which the plate caps are connected.

q. NOISE jacks—These jacks are used with an amplifier or headset to test for noise within the tube under test.

r. Meter (not labeled)—The meter indicates the tube condition on an arbitrary scale. The A LINE TEST mark at midscale establishes the correct AC line input voltage when the LINE ADJ button is depressed and the LINE ADJUST control is properly set.

s. PILOT lamp—This lamp indicates when the POWER switch is ON.

t. NEON lamp (not labeled)—This lamp indicates shorts within the tube under test when the FUNCTION switch is in positions 1 through 5.

u. FUSE lamp—This lamp serves as a protective fuse and as an overload indicator.

Theory. The TV-7/U's basic characteristics are as follows:

- Meter range—0 to 120 arbitrary units.
- Voltage—115 volts AC, ± 10 percent.
- Frequency—50 to 1,000 Hz.
- Power—115 volts at 45 watts, 50 Hz.

The TV-7/U is just one of several electron tube testers we have in the career field. The vacuum-tube tester is a necessary item of test equipment widely used in the testing and repair of electronic equipment. Since many electronic malfunctions are due to weak or faulty vacuum tubes, the tester enables the maintenance mechanic to detect tubes that are too weak for suitable operation in the prime equipment as well as to determine whether the tube is causing the entire malfunction of the system. If the average receiving tube is not overdriven or operated continuously at maximum rating, it can be expected to have a life of at least 2,000 hours before the filament opens. However, the contraction and expansion of the tube elements during heating and cooling can cause the elements to sag or lean. This condition increases the possibility of voltage arcs between the elements and decreases the coating on the emitter, which decreases conduction.

There are two types of test used to evaluate the condition of a vacuum tube: (1) *static* and (2) *dynamic*. In the static method of testing, the condition of the vacuum tube is determined by setting in stepped voltages and currents to the tube elements. This type of test is not always conclusive as it does not check the tube under actual operating conditions. The dynamic type of test checks the vacuum tube under conditions similar to the actual operation in the electronic circuit. The vacuum-tube tester discussed in this section is a dynamic type.

Vacuum-tube tests. The tests normally made with the dynamic-type tube tester are the emission test, mutual conductance test, short test, noise test, gas test, and cathode leakage test. We shall discuss each of these tests briefly.

Emission test. An important evaluation of the tube's condition is obtained by a check of the cathode or filament emission. Usually, the loss of emission or a noticeable decrease in emission indicates that the tube is reaching the end of its normal life span.

When you are making the emission test of multigrid tubes, the grids are connected to the plate, as shown in

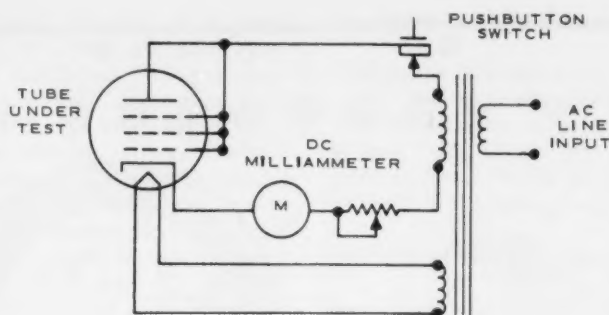
figure 6-38. A current meter and rheostat are placed in series with the tube, which is connected across the secondary of the transformer. Since the plate and grids are common tie points, they are at the same potential in respect to the cathode. The tube then acts as a diode rectifier that conducts only on alternate half-cycles when the plate is positive in respect to the cathode. The meter measures the amount of current that flows through the tube, thus indicating the condition of the cathode emitting surface. The meter face in the tube tester is divided into three areas: (1) good, (2) weak or fair, and (3) bad. Set the variable resistance to a predetermined value, according to the instructions supplied with the test set, to prevent overloading the meter. Diode tubes can be tested in the same way to determine the quality of their emitters.

Mutual conductance test. The term "mutual conductance" (or transconductance) expresses the effect of grid voltage upon the plate current of a tube. Because it simulates actual circuit conditions, the mutual conductance test evaluates the tube more accurately than the cathode emission test does. The unit of measurement in dealing with conductance is the ohm. The readings are expressed in microohms since they are so small.

As shown in figure 6-39, the dynamic method of determining mutual conductance uses a circuit that applies an AC signal to the control grid of the tube under test, in addition to a fixed bias. The tube under test serves as a load to the rectifier circuit. With a fixed bias, repressed by E_{G1} applied to the control grid, the circuit acts as a simple full-wave rectifier. When the AC signal is positive at P1, there is current flow through R1, and the meter pointer attempts to deflect in one direction. Then the AC signal reverses and P2 becomes positive. The current flows through R2, and the meter pointer tends to swing in the opposite direction. Since these changes are at a 60-Hz rate, the meter pointer remains at zero.

In addition to the fixed DC bias applied to the control grid, an AC signal from the secondary of the transformer is also applied. When this AC signal is positive at the same time that the signal is positive at P1, the meter pointer will swing more in one direction than normal. When the AC signal is positive at P2, the AC signal on the control grid is negative and the tube under test does not conduct. With P2 positive, the current flow through the meter movement tends to direct the meter pointer in the opposite direction. However, since the pointer was farther in the other direction than normal, the canceling effect does not bring it back to zero. Therefore, the meter reading indicates the amount of change in plate current caused by a change in control grid voltage under dynamic conditions. Any deviation from the rated or normal amount of mutual conductance for a specific type of tube indicates either a defective or deteriorated tube. The meter is calibrated in terms of good, weak, and bad, or it is scaled directly in microohms.

Short test and noise test. Because it shows many shorts between elements, the short test is usually one of the first steps in checking any tube. By making this test first, you protect the meter from being overloaded during other tests. A short-circuit test is usually sensitive enough to indicate a resistance leakage of less than one-fourth of a megohm, and the heater voltage is applied so that any tube elements that



NGE13-81

Figure 6-38. Basic emission test circuit.

might short during normal operation will be detected. If the tube is shorted, further testing of the tube is unnecessary.

Figure 6-40 shows the basic circuit used for the short test. In the schematic the plate switch is in position 2 and all other switches are in position 1. If the plate element is touching any other element within the tube, the AC circuit in the secondary of the transformer will be complete and both plates of the neon lamp will glow. If none of the elements are shorted to the plate, only one plate of the neon lamp will glow. You can switch each element into the circuit and individually check it for a short to other elements. R2 limits the current through the lamp to a safe value. R1 bypasses any small alternating currents in the circuit that might be caused by stray capacitance preventing the neon lamp from indicating erroneously.

The noise test is nothing more than a very sensitive short test. A high-gain amplifier or headset can be connected to the jacks on both sides of the neon lamp. If an amplifier is used, the antenna is connected to one jack and the ground terminal of the receiver connected to the other. If the tube elements are loose, you can hear noise or static from the headset or amplifier speaker. You can also use an AC output meter to check for noise by placing the two leads into the noise test jacks.

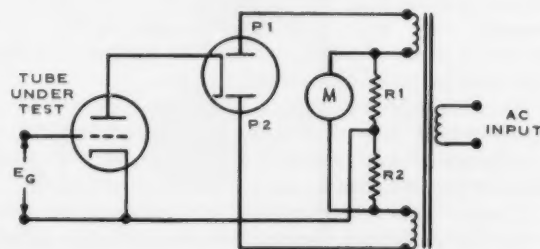
Gas test. The presence of gas in most tubes is undesirable. When gas is present, the electrons emitted by the cathode collide with the molecules of gas. This action dislodges electrons from the gas molecules, and positive gas ions are formed. These ions are attracted by the control grid of the tube. Because the control grid is negative, the ions absorb electrons from the grid circuit in order to revert to more stable gas molecules. If the gas in the tube is appreciable, the collisions between the gas molecules and the cathode-emitted electrons release many secondarily-emitted electrons, and the resulting flow of grid current is high.

The gas test indicates whether or not excessive gas is present in the tube. The basic circuit used for the test is shown in figure 6-41. With switch S1 set to position 1, a certain amount of plate current is measured by the DC

milliammeter. If the amount of gas in the tube is normal for that tube type, the meter reading will not change with switch S1 in position 2. If more than the normal amount of gas is present in the tube, current flows through the grid resistor, causing a voltage drop with the polarity as shown. The effect reduces the negative bias voltage on the control grid, allowing the tube to conduct harder and increase plate current. Small increases are normal and large increases indicate the presence of gas.

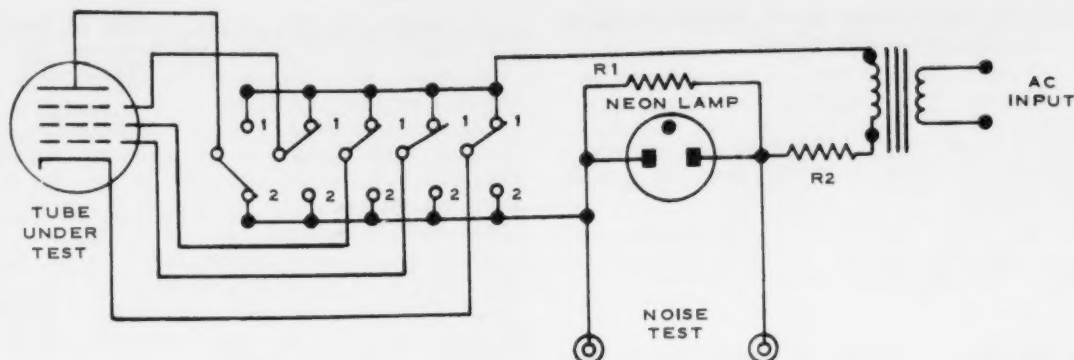
Cathode leakage test. The cathode of the tube is an important element because it supplies the electrons needed for tube operation. The heater is usually a tungsten alloy wire, enclosed in, but insulated from, the tubular metal cathode sleeve. The cathode is coated with a strontium or barium compound that emits electrons when it is heated. The heater must be placed as close as possible to the walls of the cathode to allow maximum heat exchange. Continuous heating and cooling sometimes causes the insulation to become brittle and cracked. This condition develops into a high-resistance leak between the elements and causes the tube to become noisy and the emission rate to decrease.

The cathode leakage test measures the amount of leakage, if any, between the cathode and the heater elements. It is often made in conjunction with the short test,



NGE13-105

Figure 6-39. Basic dynamic mutual conductance test circuit.



NGE13-80

Figure 6-40. Basic circuit for shortand noise test.

though some tube testers are designed to make this test as a separate operation.

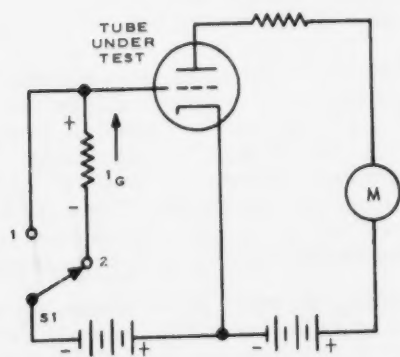
Figure 6-42 shows the basic circuit that is often used to make the cathode leakage test. With switch S1 in position 2, a certain amount of plate current flows. With the switch in position 1, the cathode becomes a floating element. If there is no leakage between the elements, the meter reading is zero. If the elements are shorted, the plate current reading will be the same as it was with the switch in position 2. Any slight meter reading indicates that a certain number of leakage is taking place.

Use in field. To be of practical use to the technician in the field, a tube tester must evaluate the quality of a tube quickly and accurately and with minimum effort on the part of the operator. In order to save time and effort, accuracy is sacrificed to some extent. Field-type tube testers, cannot accurately evaluate the function of the tube in its operational circuit. Often a tube that checks out all right in the tester does not operate efficiently in its operational circuit because of the critical characteristics of the circuit.

When this occurs, you must place other tubes of the same type in the circuit one at a time until you find one, with the proper characteristics, that functions correctly.

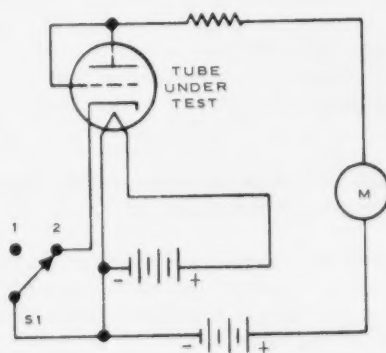
Exercises (074):

1. There are two types of electron tube testers. What type of tube tester is the TV-7/U?
2. When should you depress the RECT button on the TV-7/U test set?
3. Variances in AC line voltage are compensated for by which control of the TV-7/U?



NGE13-104

Figure 6-41. Basic gas test circuit.



NGE13-79

Figure 6-42. Basic cathode leakage test circuit.

4. Normally, what does a noticeable decrease of cathode emission in a vacuum tube indicate?
5. Why does the mutual conductance test evaluate a vacuum tube more accurately than the cathode emission test?
6. In the dynamic method of determining mutual conductance, how is the meter calibrated?
7. Briefly describe the noise test.
8. How is a vacuum tube affected by a high-resistance leak between its elements?
9. What action should you take if a tube checks out all right in the tester but does not operate efficiently in its operational circuit?

6-3. Organizational and Intermediate Level Maintenance on Category I and Category II Test Equipment

Economy, mission, and combat effectiveness demand that maximum maintenance be performed at the lowest practical organizational element. Because of the location of most of our units, both organizational and intermediate levels of maintenance are performed on station or site. This scope of responsibilities also include test equipment. Firm maintenance discipline is necessary, and all supervisors must maintain self-sufficiency at this level. Let's look at our responsibilities for organizational and intermediate level maintenance of Category I and Category II test equipment.

075. Identify the level of maintenance required for specific categories of test equipment.

Test Equipment Categories. For maintenance purposes, test equipment is divided into two categories. All test equipment in your area of maintenance responsibility falls within the following categories.

(1) **Category I**—This category includes all operational test equipment installed in a system as an integral part of the system. Examples of this category are the ammeters, voltmeters, and oscilloscopes that are built into the system.

(2) **Category II**—This category includes all equipment that is used to check Category I test equipment. This group may include such devices as the PSM-6 multimeter, counters, and frequency meters.

Don't misunderstand. You are not responsible for all Category I and Category II test equipment, but all the equipment that you are responsible for falls into one of these two categories. Full explanations of responsibilities toward PMEL is contained in TO 33K-1-100.

There are two organizations that have the primary responsibility for maintaining equipment in Categories I and II. These are (1) the using organization of which you are a part, and (2) the bases's precision measurement equipment laboratory (PMEL). As part of the using organization, you have the responsibility for the calibration of your Category I and Category II equipment, with the following exceptions.

a. Base PMEL calibrates all the general-purpose and commercial Category II test equipment that can be removed to the PMEL. This does not include the test equipment that must be calibrated while it is in data processing equipment.

b. Maintenance of test equipment that requires special skills or special equipment (whether it be Category I or II) that is available only at the PMEL is the responsibility of the base PMEL.

Levels of Maintenance. As was mentioned earlier, we'll be working with two levels of maintenance, (1) organizational and (2) intermediate. In the following discussion we'll cover each level.

Organizational. Organizational maintenance on precision measurement equipment normally consists of preventive maintenance operations performed by the equipment's users, operator, or operating crew. This preventive maintenance is limited to the proper use, cleaning, preservation, servicing, minor repairs, and accomplishment of work specifically designated as organizational maintenance by technical directives. Excluded is any work that requires the adjustment or replacement of parts or components that affect the calibration of the equipment.

Intermediate. Intermediate maintenance includes the maintenance of precision measurement equipment that is beyond the responsibility of the organizational maintenance activity. This includes repairs requiring fixed laboratory and ground mobile equipment, the replacement of major unit assemblies and components, and the fabrication of parts. Category III precision measurement equipment is used for maintenance, troubleshooting, testing, verification, and calibration of non-PMEL equipment as well as Category I and Category II test equipment; it is maintained by the precision measurement equipment laboratory (PMEL), using Category IV test equipment.

Scheduling. The PMEL should automatically reschedule your test equipment and call for it when its calibration is required. If you determine that calibration is required sooner than the scheduled date; you must contact PMEL and have that particular test set rescheduled. When possible, you must report your regular calibration requirements to the PMEL to ensure prompt compliance.

Additional test equipment information. There are two additional bits of information about test equipment that you need to be aware of, (1) handling/transporting and (2) limited calibration. Personnel in this career field often work at units located away from their support base—oftentimes, over 150 miles or more. The support base normally has the PMEL facilities to support our units and we have to transport the PME units back and forth. PME units are delicate instruments and must be treated as such. Your PMEL monitor will have the guidance on how PME units should be transported and cared for. Also, some PME units are going to be too heavy or bulky for one person to handle. If you're ever in doubt about being able to lift a unit, get help. These instruments are expensive and delicate and can not take abuses like being dropped or bumped around in a vehicle. Remember, handle PME units with care.

The second bit of information about test equipment concerns limited calibrations. PME units, that have been calibrated to the accuracy levels or capabilities that are less than those specified by the appropriate calibration procedures, are considered to have limited calibration. What all this means is that a particular PME unit can still be usable even though some accuracy levels or some capabilities of the unit are not within specifications. Normally, the PMEL facility will contact the user to see if the user can still use the PME unit even though the unit has limitations. If the using facility can still use the PME unit,

with the limitations, the PMEL facility will mark the calibration tag as being a "limited calibration." Since the marking procedure is subject to change, your unit's training program will have to train you to recognize "limited calibration" identification labels. The main thing is to know about the limitations and to use the equipment accordingly.

Exercises (075):

1. What type test equipment does base PMEL calibrate?
2. At what level of maintenance is preventive maintenance, short of adjustment or parts replacement on test equipment, normally performed?
3. What type test equipment is included in Category I?
4. What does "limited calibration" mean?

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Instructional Manual, Type 453/R453 (Oscilloscope above 2N 20,000), Tektronix, Inc., Beaverton, Oregon.
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Answers for Exercises

CHAPTER 1

Reference:

- 001 - 1. Radiation Hazards sign.
2. Electrical shock.
3. Falling objects from heights.
4. Equipment blowers and/or motors.
5. Cleaning agent vapors cause breathing problems or vision problems, skin irritations, or equipment damage.
6. Congested work area.
7. Trailer pinning someone.
- 002 - 1. Handle with care, follow directives, and if tube is broken use proper tools and methods for clean up.
2. Be aware of what actions you're about to perform, what dangers exist, and how to react if shocked.
3. Post an "Interlock Open" or "Interlock Override" sign.
4. Ground or discharge it.
5. First establish your balance at the new height.
6. Use cleaning agents only in well ventilated areas.
7. The use of gloves or something to protect your bare hands.
- 003 - 1. Let the wound bleed, don't suck it, wash the wound with soapy water, and then flush it with clean water.
2. Nonconductive.
3. Keep the victim calm and still, try to establish how badly the victim is injured, and keep him or her warm, monitoring for signs of shock.
4. Alcoholic drinks.
5. AFP 50-34.

CHAPTER 2

- 004 - 1. Field publication.
2. Field publication.
3. Departmental publications.
- 005 - 1. Non-Air Force publications.
2. Standard publications.
3. Periodicals.
- 006 - 1. The number is a basic number or coded number showing that the directive covers a basic subject. Example: 35 covers personnel.
2. The specific area each major heading covers.
- 007 - 1. The 00-5 series.
2. Seven.
3. Indicates the type or design series of equipment.
4. Group 3.
5. TO 0-1-33.
- 008 - 1. A technical manual (service manual).
2. A technical manual (circuits and diagram).
3. A preliminary TO.
- 009 - 1. To report TO errors such as insufficient information needed to perform adequately a task or function.
2. AFTO Form 22.

CHAPTER 3

- 010 - 1. To serve as the executive manager of the maintenance organization, planning, scheduling, and controlling all maintenance activities.
2. Through staff agencies that are responsible for the various functions.
- 011 - 1. Maintenance Control.
2. It is responsible for reports, correspondence, local maintenance directives, and keypunch services.
3. To improve the overall maintenance operation by analyzing maintenance data and statistical inputs.
4. Quality Control.
5. Job Control, Materiel Control, and Plans and Scheduling.

6. Information concerning programs to be supported and their impact upon available resources.
7. Directs and coordinates the maintenance production effort.
- 012 - 1. To enter accurate and complete data on the AFTO Form 349.
2. A job that has a definite beginning and end.
3. To TO components that have a fixed life expectancy.
4. An item on which study is being made to determine its life expectancy.
5. Items of equipment on which reports are required by item serial numbers.
- 013 - 1. Only for removal and replacement of items identified by an asterisk in the WUC manual.
2. When the Form 349 is used as a dispatch form.
3. The manufacturer's part number.
4. When a "serially controlled" item is removed or modified.
5. The last three digits of the AFTO Form 350 tag modified.
- 014 - 1. From the information on the AFTO Form 349.
2. A brief description of the work done on the part, if the part is serviceable. Otherwise, NRTS is entered.
3. Production Control/RPC.
4. The agency responsible for returning an item to serviceability.
5. Status change to "awaiting parts."
- 015 - 1. When an item creates two or more MICAP reportable conditions or when two or more cannibalizations occur within a 30-day period.
2. Equipment that requires bench checking and/or repair.
3. Supply items that are needed for replacement during forthcoming periodic inspections.
- 016 - 1. A green tag, DD Form 1577-2.
2. A qualified inspector.
- 017 - 1. Category I.
2. As a Category I or DULL SWORD.
3. Category II.
4. Because they are reported under the TO improvement program.
5. The quality control section.
- 018 - 1. If not corrected quickly, the substandard condition could become accepted as the standard.
2. During the daily activities.
3. By analyzing the maintenance reports.
4. Care must be taken to ensure that the charts and graphs are readable and understandable.
- 019 - 1. TAs are based on the mission assigned to an Air Force activity.
2. The major commands and Allowance and Authorization (A&A).
3. Items which are either consumed, or lose their original identity by incorporation into another assembly.
4. Allowance and Authorization (A&A).
- 020 - 1. (1) Cash Collection Voucher, DD Form 1131, and (2) Statement of Charges, DD Form 362.
2. The top price is the full price while the bottom price is the price the Air Force is to collect from the individual. This reduction is allowed but may not exceed 25 percent.
3. His or her signature on the statement of charges form indicates: (1) acknowledgement, (2) authorization, (3) waiver of right, (4) an affirmation, and (5) an agreement.
- 021 - 1. It explains and records circumstances involving lost, damaged, or destroyed Air Force property.
2. The individual who has custodial responsibility at the time of loss.
3. No later than 30 days.
- 022 - 1. (1) Modification of equipment, (2) excessive overtime, (3) additional duties, (4) additional operating hours.
2. To ensure that he or she has all the facts straight before going to higher command for assistance.

CHAPTER 4

- 023 -
 - 1. Intermediate.
 - 2. Depot.
 - 3. Organizational.
- 024 -
 - 1. The unit's mission.
 - 2. During downtime.
- 025 -
 - 1. Inspections.
 - 2. Performance check.
 - 3. Air filter cleaning.
- 026 -
 - 1. Causes rapid increase of corrosion.
 - 2. Exposed area should be recoated with a new coat of lacquer or varnish.
- 027 -
 - 1. Items b, c, and d.
 - 2. By comparing data accumulated over a long period of time.
- 028 -
 - 1. The equipment's TO.
 - 2. In the original container.
 - 3. By their body, not their pins.
- 029 -
 - 1. Performance check.
 - 2. Troubleshoot, align, and performance check.
 - 3. Alignment check.
- 030 -
 - i.
 - a. Class V.
 - b. Class II.
 - c. Class IVB and Class IV.
 - d. Class IVA.
 - e. Immediate action.
 - f. Urgent action.
- 031 -
 - 1. Any of the following:
 - a. Any item or condition that may affect the well-being or safety of personnel.
 - b. Poor equipment performance, short equipment life, or early part failures.
 - c. A difficulty in removing or installing certain components, units, or parts, which can be remedied by a change in procedures.
 - d. Repeated equipment failure caused by failure of one or more parts of the same type or make.
 - 2.
 - a. Inventory the kit.
 - b. Read the TCTO instructions. Make sure you understand them.
 - c. Check the TCTO to find out when the work must be completed.
 - d. Prepare for the job.

CHAPTER 5

- 032 -
 - 1. The 60:40 and 63:37 solders.
 - 2. 63:37 solder.
 - 3. Used to remove oxidation from the metal surfaces to be soldered.
 - 4. Corrosive fluxes will eat away the metal and destroy the electrical connection.
- 033 -
 - 1. Because they have a controllable heat output.
 - 2. So that you can bend the component leads without nicking, scraping, or damaging the lead or component.
 - 3. A pencil-style typewriter eraser.
- 034 -
 - 1. Higher quality work, less time required to complete the task, and improved worker safety.
 - 2. Wiping the tip with a rag or canvas pad.
 - 3. To eliminate the possibility of electrical shock.
- 035 -
 - 1. The action of molten solder on metal is like the action of water on salt. The solvent or intermetallic solution action chemically dissolves part of the metal surfaces to be joined and at temperatures well below the melting point of the metals being joined.
 - 2. The soldered connection is chemical and has metal continuity. A wired or bolted connection never makes good electrical contact because of the insulating film on the surface of the metals.

- 036 -
 - 1. The size, the wattage, and the shape of the tip.
 - 2. The tip must not be so large that it obscures your vision or damages adjacent parts of wire insulation, but it must be the proper size and shape to produce the best solder joint.
 - 3. Square.
 - 4. To prevent oxidation.
- 037 -
 - 1. If you apply heat to a rosin wick, the solder will flow readily into the rosin area, leaving the terminal to which it was previously affixed.
 - 2. Place the wick on top of the solder joint to be removed; place the iron tip on top of the wick; when the iron melts the solder, it will flow into the wick; as the wick becomes saturated, clip off the end of the wick. Repeat these steps until you remove all the solder from the joint.
 - 3. "Sniffing" removes the molten solder by suction.
 - 4. The wicking method.
- 038 -
 - 1. The strands should be in their original lay and there should not be any nicks in the wire or any insulation damage.
 - 2. Approximately the diameter of the wire.
 - 3.
 - (1) Strip the wire carefully, using one of the recommended tools.
 - (2) Clean off all impurities from the components to be soldered.
 - (3) Tin the conductor to the depth required.
- 039 -
 - 1. The space between the post must be filled. Use additional tinned wire or bend the conductor into a U-shape if the double diameter of the wire will fill the space.
 - 2. 1/32 inch.
 - 3. The lower section.
- 040 -
 - 1. 1/32 inch.
 - 2. The leakage current of some soldering irons is enough to damage transistors and small semiconductor devices.
 - 3. Stop the soldering process and let the connection cool completely. Then repeat the soldering process as necessary.
- 041 -
 - 1. Clinched and unclinched.
 - 2. The unclinched lead termination is used in special cases where the parts are light and no stress is placed on the solder connection.
- 042 -
 - 1. First clean the conductive strip that is to be repaired (do not use a wire brush for this operation), and repair the conductor break by flowing solder over the entire break.
 - 2. Clean the area to be repaired first. Bridge the peeling area with a bare wire, and apply solder along the entire length of the wire to bond it solidly to the conducting strip.
 - 3. You should secure the board in a repair vise.
- 043 -
 - 1. As close to the body of the defective part as possible.
 - 2. Fashion a small loop at both ends of the new component; slip the loops over the ends of the cut defective component leads; secure the connections by bending the old leads away from the component body. Place a heat sink near the place where the lead enters the circuit board (this prevents unsoldering the old lead); solder the lead and component together. Make sure the old leads are still secured to the circuit board.
- 044 -
 - 1. First clean the board with a white pencil-style typewriter eraser. The pad is clean when the whole pad shows a bright uniform appearance. The final step is cleaning the pad with a brush and alcohol.
 - 2. The whole pad has a uniform gold-pink appearance.
 - 3. Place the iron tip flat against the side component lead and center it on the pad. Form the bridge between the iron tip and the component lead. Move the solder down the lead to the end of the wire. Tin the cut in the end and then move the pad back to the soldering iron.
- 045 -
 - 1. Pressure (7), vacuum (8), minichine (18).
 - 2. As required to protect the component being worked on from stray currents.
 - 3. Tungsten and carbon-type resistive heating elements.
 - 4. Just enough to melt the solder.

- 046 - 1. Dry localized areas rapidly; accelerate curing process for coating and bonding materials; and troubleshoot.
 2. Match the tip to the work; select a loose fit for proper molten solder and airflow; use the largest tip that can be safely applied. (Any three requirements discussed in text.)
 3. To provide low-contact-point resistance and reduce the possibility of arcing.
 4. Using the right temperature.
 5. It can be used for soldering and desoldering applications when the workpiece may be damaged by high-current flow or arcing.
- 047 - 1. Oil the spindle at least each 10 hours of operation, and oil the shaft if any vibration is noticed.
 2. The filter should be replaced as often as required to maintain full vacuum flow.
- 048 - 1. The amount of current that must be carried.
 2. Place it into the vise with the wiring cup side up and the pins in horizontal rows. Be careful not to overtighten the vise.
 3. 5/8 inch.
 4. A 20-foot cable would require an outer cable housing 20 feet 4 inches long.
 5. First cut the cord about 2 inches longer than the length needed to make twelve turns around the harness. Form one end of the cord into a 1-inch loop and place it flat on the harness, parallel to the wiring. Wind twelve turns tightly over this loop and, at the last turn, push the cord in through the loop that extends from under the wrap. Pull the end of the cord that was looped until the loop is about half way under the wrap.
 6. Because it minimizes insulation damage.
 7. So the cord will not loosen.

CHAPTER 6

- 049 - 1. Remove power and detach at least one end of the resistor before attempting measurement.
 2. Up to approximately 1,000 Hz.
 3. To prevent "loading" the solid-state circuits.
 4. Digital multimeter.
 5. The meter needle deflects in the opposite direction and possibly can be damaged as it's driven into the stop.
- 050 - 1. Power supply, CRT, and the X and Y amplifiers.
 2. Y channel amplifier.
 3. They are more reliable and require less calibration.
- 051 - 1. Very narrow.
 2. Horizontally on the CRT.
 3. 60-second delay.
- 052 - 1. Alignments of tuned circuits.
 2. By frequency (audio vs radio).
 3. TO 31-1-141-7.
- 053 - 1. A simple and quick appraisal of the quality of a tube.
 2. Emission-type and the transconductance-type testers.
- 054 - 1. Into a radar's RF plumbing or waveguide.
 2. Manually by turning a calibrated tuning dial.
 3. The dial indicates the transmitter frequency.
- 055 - 1. 1,000 volts.
 2. AC.
 3. By using an alligator clip attachment.
- 056 - 1. #2, Polarity indicator.
 2. Function: DC; Range: 20V or AUTO.
 3. To the INT position.
- 057 - 1. DC level to 50 MHz.
 2. AC, ground, DC.
 3. INT, LINE, EXT, AND EXT ÷ 10.
 4. When two input signals are to be compared.
 5. A TIME/DIV.
 6. 0.2 microsecond/division.
 7. A TIME/DIV and the DELAY-TIME MULTIPLIER control.
- 058 - 1. AC voltage, DC voltage, and voltage comparison measurement.
 2. Two.
 3. +175 volts.
 4. CAL position.
 5. +216 volts.
- 059 - 1. The sweep speed will be multiplied by 10.
 2. Some distortion of the picture will result from a nonlinear sweep.
 3. CAL.
 4. 300 microseconds.
 5. 1.667 kHz.
 6. 1-microsecond position.
 7. The reference point of the reference signal is placed on a vertical grid line and the horizontal difference is measured beginning at that grid line.
- 060 - 1. a. Display the two pulses on the trace.
 b. Include both pulses in an intensified portion of the trace.
 c. Set the first pulse on a vertical grid line; note dial setting.
 d. Adjust the DELAY-TIME multiplier dial until the second pulse appears where the first pulse had been.
 e. Subtract the first dial reading from the second dial reading and multiply by the delay time on A TIME/DIV switch.
 2. 0.51 milliseconds.
 3. Apparent magnification is 200 times.
 4. .5 millisecond.
 5. 1.5 microseconds.
- 061 - 1. In the fuse holder.
 2. The ON indicator.
 3. The CH1 or X Control.
 4. The LEVEL control.
 5. LINE position.
- 062 - 1. #9, Frequency Control.
 2. From 3 to 300 microseconds.
 3. The POWER SET control.
- 063 - 1. 608E.
 2. The MODULATION control.
 3. The MEGACYCLES dial.
- 064 - 1. The ΔF or delta F control.
 2. The FREQUENCY meter.
 3. The LINE VOLTAGE device/switch.
- 065 - 1. Either by tapping into the RF transmission line through a directional coupler or by use of a small pick-up antenna placed in the RF beam.
 2. On the face window of the output meter.
- 066 - 1. 39 dBm.
 2. First, ensure that no RF is applied. Second, set the range switch to the range to be used.
- 067 - 1. This module generates, mixes, and demodulates the RF signals required to check the interrogator transmitter and receiver.
 2. This module produces test SIF pulse trains, triggers, and pulses for testing and aligning the SIF interrogator, transponder, and display system equipment.
- 068 - 1. A pulse train that includes a fixed pulse in the X position of the pulse train.
 2. WIDTH ADJ control.
- 069 - 1. Fixed 1,090-MHz CW, 1,070-1,110-MHz sweep frequency signal, frequency markers representing the center frequency and the ± 3 , ± 5 , ± 10 , and ± 20 MHz points of the sweep frequency, and a sweep sync output to sync the oscilloscope.
 2. Three simulated radar video pulses, active readout signals representing a specific target area, and antenna azimuth rotation data consisting of ACPs and ARPs.
 3. It is a 60-MHz ± 20 -MHz sweep signal.

- 070 - 1. 1,030-MHz CW, 1,010-1,050-MHz sweep frequency signal, frequency markers, sweep sync, and heterodyned video.
2. To generate, mix, demodulate, and control the RF level of the signals required to test and align the interrogator transmitter and receiver equipment.
- 071 - 1. By selecting the required markers with the XTAL MARK (USEC) switch.
2. To the FREQ MARK IN jack in the vertical section of the oscilloscope.
- 072 - 1. Never connect shorted cables to the test set, doublecheck your connections, do not let the cables and probes lie on the floor, and use cables of the right length.
2. To set the controls to specified positions that will enable the technician to obtain the correct indications to perform the test procedures.
- 073 - 1. X-band; 8.4 to 10.0 GHz.
2. +50 dBm; all our radars can exceed it.
3. When using the signal generator function.
4. In the RF in PWR (dBm) position a direct reading of peak power, at the test set, is made from the numeric display.
- 074 - 1. Dynamic mutual conductance type.
2. To test rectifier tubes used in power supplies.
3. LINE ADJUST control.
4. That the tube is reaching the end of its normal life span.
5. Because it simulates actual circuit conditions.
6. In terms of good, weak, and bad.
7. It is a very sensitive short test that checks for loose connectors.
8. It becomes noisy and the emission rate decreases.
9. Place similar tubes in the circuit one at a time until you find one, with the proper characteristics, that functions correctly.
- 075 - 1. All general purpose and commercial Category II test equipment that can be removed to the PMEL.
2. Organizational.
3. All operational test equipment installed in a system.
4. It basically means that some part (accuracy or function) of a PME unit is not calibrated or usable.

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